



**ASIC**  
COSTA RICA

THE 24<sup>TH</sup> INTERNATIONAL  
CONFERENCE ON COFFEE SCIENCE  
**November 11-16, 2012**  
[www.asic2012costarica.org](http://www.asic2012costarica.org)

## PROGRAMME & ABSTRACTS



**AGRONOMY | BIOTECHNOLOGY**  
**PHYSIOLOGY | CHEMISTRY**  
**PROCESSING | COFFEE & HEALTH**  
**SUSTAINABILITY | CLIMATE CHANGE**  
**COFFEE QUALITY | PESTS & DISEASES**  
**GENOMICS & GENETICS**





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# WELCOME

Dear Colleagues,

It is a great pleasure to announce that the **24th ASIC International Conference on Coffee Science, ASIC 2012**, will take place in San José, Costa Rica, from November 11th to 16th, 2012.

ASIC warmly accepted the invitation of ICAFE, the Costa Rican Coffee Institute, for the organization of this unique coffee event.

It is the first time that ASIC Conference will happen in a Central American country. The remarkable efforts to preserve in this unique area of production very high standards of quality let anticipate scientific communications of great interest.

Coffee scientists have to face several important challenges among them the rapid climatic change. ASIC 2012 will be the platform to report and debate on the proposed solutions aimed to preserve the quality and the quantity of the different origins. Other topics of interest will be in the agenda of the Conference, such as the relationship between coffee consumption and human health.

With areas of coffee production nearby San José, the opportunity to combine visits of coffee plantations with natural volcanic beauties of Costa Rica will be numerous.

The traditional hospitality of Costa Rica and other Central American countries let anticipate an unforgettable ASIC 2012 Conference.

We look forward to meeting you in San José, Costa Rica, in November 2012.

Mr. Andrea Illy  
**President ASIC**





## **MESSAGE**

**Chairman, Local Organizing Committee of the 24th International Conference on Coffee Science**

**Vice Minister, Ministry of Agriculture and Livestock of Costa Rica**

Central America is excited to host for the first time the 24th International Conference on Coffee Science and is an honor for Costa Rica to be the venue chosen by ASIC. This conference will offer a wealth of knowledge in preserving our unique area of production, while providing stimulating scientific discussions of great interest. This translates as a great opportunity for the region and also to continue introducing Costa Rica as a producing country.

This year during this meeting we'll developed varied topics of coffee as Chemistry, Climate Change, Agricultural Management, Sustainability, Genetics, Quality Processing, Biotechnology, Human Health, roasted and ground, Carbon Neutral and Ecophysiology, which undoubtedly result in an appropriate forum for the capture and transfer of technology to the source.

Furthermore, the last day of activities, participants will visit CATIE, a worldwide renowned tropical agricultural research center in Turrialba, which has a scientific approach focused in genetics and varieties research. ASIC's standing success has been made possible solely upon voluntary sponsorships by special supporters, to whom we extend a warm thank you.

Hope you will enjoy your stay in Costa Rica and WELCOME!!

**Mrs. Xinia Chaves**





## MESSAGE

### Executive Director, The Costa Rica Coffee Institute, ICAFE

Since the beginning of the XVIII Century, and throughout our country history, coffee has been a keystone for the Costarican society.

ICAFE is a public, non-governmental institution that was established in 1933 to promote the national coffee growing activity, motivating an ethical and unique production model for national Coffee Growers, Millers, Roasters and Exporters. It supports national coffee production and milling, as well as national and international coffee marketing.

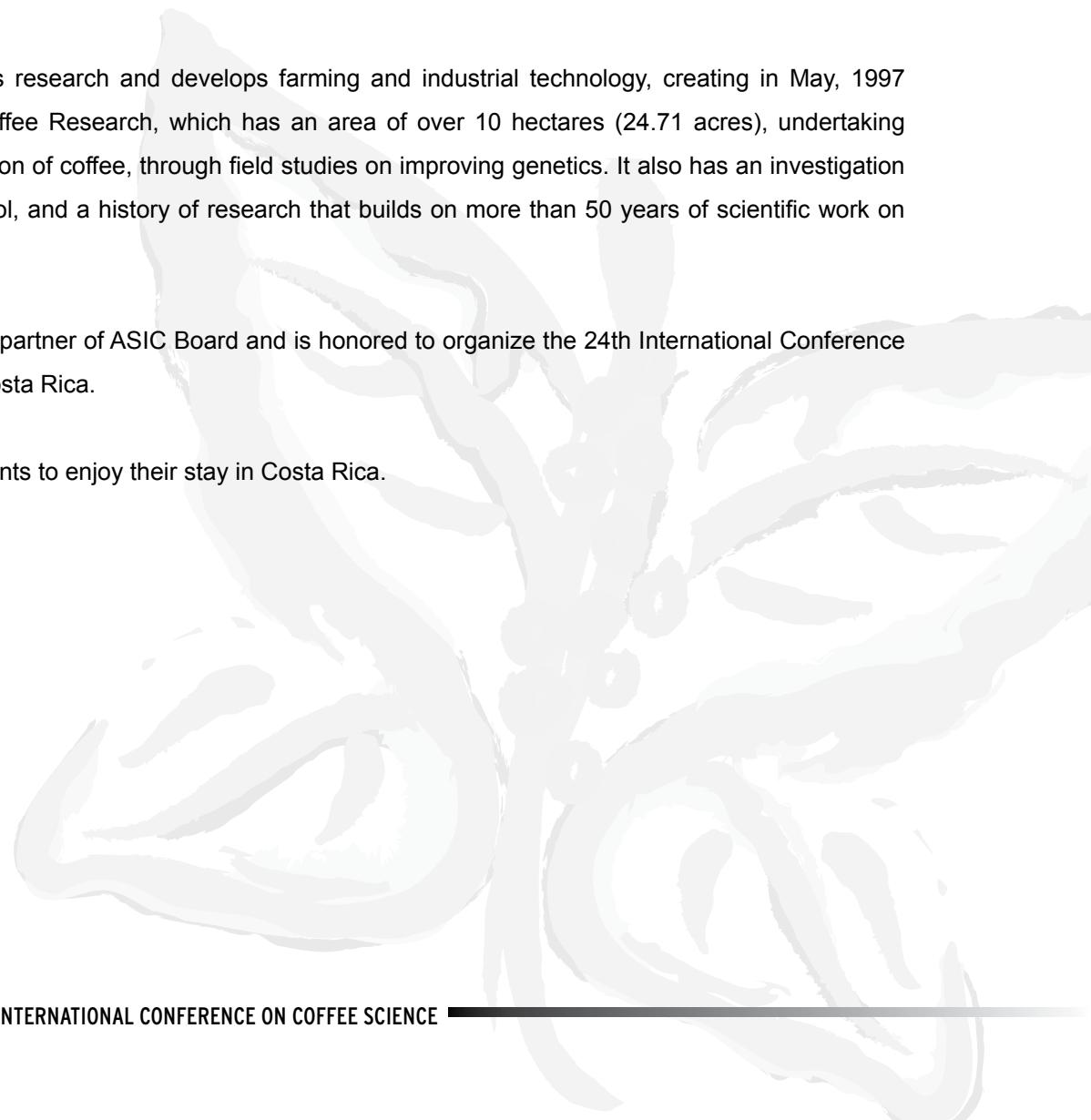
ICAFE also encourages research and develops farming and industrial technology, creating in May, 1997 CICAFE, Center for Coffee Research, which has an area of over 10 hectares (24.71 acres), undertaking research on the cultivation of coffee, through field studies on improving genetics. It also has an investigation laboratory, quality control, and a history of research that builds on more than 50 years of scientific work on coffee in Costa Rica.

ICAFE is happy to be a partner of ASIC Board and is honored to organize the 24th International Conference on Coffee Science in Costa Rica.

I wish all of the participants to enjoy their stay in Costa Rica.

**Mr. Ronald Peters S.**

**ooIcafe**  
Instituto del Café de Costa Rica



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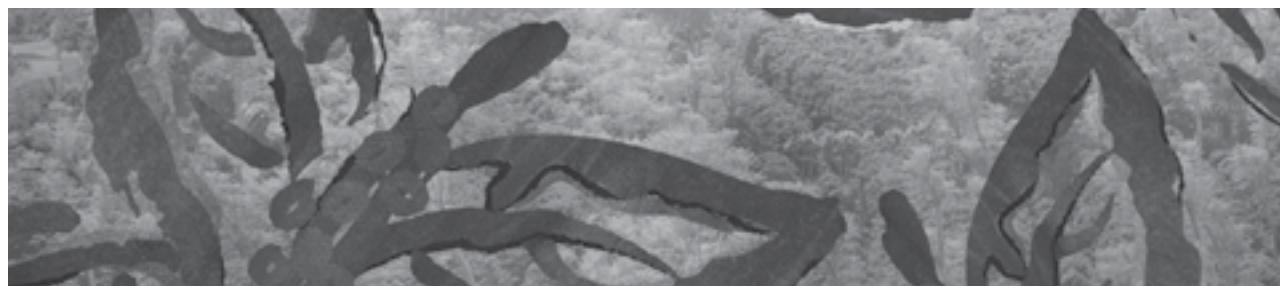
Mr. Herbert van der Vossen – Ecophysiology and agronomy

## General Organization

**Costa Rica's Coffee Institute ICAFE**

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# PROGRAMME



**Sunday November 11, 2012**

18:00      Welcome Cocktail Reception (Pueblo Antiguo) Sponsored by:

**Monday November 12, 2012**9:00      **Opening Ceremony**

Speeches by:

- Dr. Andrea Illy, President of ASIC
- Dr. Roberio da Silva, ICO Executive Director
- Mrs. Xinia Chaves, Vice Minister of Agriculture, President of the Organizing Committee
- Mrs. Laura Chinchilla, President of the Republic of Costa Rica

11:00      **Central America Coffee Situation:**

- Dr. Victor Villalobos, General Director, Inter American Institute for Cooperation on Agriculture.

12:00      **Lunch. Sponsored by:**Ministerio Federal del  
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Press Conference. Participation upon invitation

**Coffee Consumption & Human Physiology****Chairpersons : A.Nehlig (France) & J. Coughlin (USA)**

- 13:30      Coffee and cancer: a benefit-risk evaluation of the experimental and epidemiological evidence (H1)  
*Nehlig, A. & Coughlin, J. R.(France & USA)*
- 14:15      Caffeine and age-related cognitive decline (H2)  
*Ritchie, K. (Australia)*
- 15:00      Does coffee intake reduce type 2 diabetes mellitus risk? (H3)  
*Pimentel, G. D. (Brazil)*
- 15:45      Neuroprotective effect of coffee in Parkinson disease (H4)  
*Costa, J.(Portugal)*
- 16:30      Coffee break

**Chairpersons: V. Somoza & J. Coughlin**

- 16:45      Coffee and coffee constituents for promoting body weight-maintenance in healthy subjects (H5)  
*Somoza, V., Riedel, A.(Austria)*
- 17:00      Blanching and air drying effect on antioxidant capacity and fiber content of processed coffee pulp for human consumption (H6)  
*Cubero, E., Bolaños, C., Bonilla, A. R., Vargas, P.(Costa Rica)*

17:15	Coffee polyphenols protect plasma and LDL from postprandial oxidative modification in human ( <b>H7</b> ) <i>Sirota, R., Gorelik, S., Harris, R., Kohen, R., Kanner, J. (Israel)</i>
17:30	Development of acrylamide-free “ready-to-drink” coffee by Aspergillus oryzae ( <b>H8</b> ) <i>Iwai, K., Fukunaga, T., Narita, Y., Nakagiri, O., Tsuboi, H., Bogaki, T., Sano, M., Ozeki, K. (Japan)</i>
17:45	Coffea arabica: anti-inflammatory activity of aqueous extracts ( <b>H9</b> ) <i>Moreira, M. E., Pereira, R., Dias, D., Gontijo, V., Vilela, F., Moraes, G., Giusti-Paiva, A., Dos Santos, M. (Brazil)</i>
18:00	End of the session
18:00	<b>Poster Session – Chemistry-Physiology-Processing</b>
19:00	End of session

## Tuesday November 13, 2012

### Coffee Chemistry

**Chair persons: M. Petracco (Italy) & A. Farah (Brazil)**

8:30	The multiple role of polyphenol chemistry in coffee associated with quality attributes ( <b>C21</b> ) <i>Blank, I. (Switzerland)</i>
9:15	Differentiation of the Robusta and Arabica varieties by on-line analysis of the chemical signature in the roasting-gas inside of individual coffee beans during roasting by microprobe-sampling photo-ionisation mass spectrometry ( <b>C1</b> ) <i>Hertz, R., Streibel, T., Grabowski, J., Zimmermann, R. (Germany)</i>
9:30	On-line analysis of the coffee roasting process with PTR-TOF-MS: changes in flavor formation for different coffee varieties ( <b>C5</b> ) <i>Gloess, A. N., Vietri, A., Bongers, S., Koziorowski, T., Yeretzian, C. (Switzerland)</i>
9:45	Physiological markers for quality coffee beverage ( <b>C18</b> ) <i>Rosa, S. D.V.F., Freitas, M. N., Pereira, C. C. (Brazil)</i>
10:00	Quality “in cup” of espresso coffee: data from over ten years of investigation ( <b>C20</b> ) <i>Severini, C., Romani, S., Cevoli, C., Derossi, A. (Italy)</i>
10:15	Coffee break. Sponsored by:



### Coffee Chemistry

**Chair persons: I. Blank (Switzerland) & C. Severini (Italy)**

10:45	Impact of crema quantity and appearance on expected and actual coffee perception ( <b>C13</b> ) <i>Folmer, B., Pineau, N., Dugas, V., Sudre, J., Labbe, D., Germain, J.C., Kolodziejczk, E., Pollien, P., Matthey-Doret, W., Ali, S., Garcia, S., Rozo, L., Hartmann, C., Martin, N., Barron, D. (Switzerland)</i>
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- 11:00 Free amino acids determination in green coffee beans by GC-MS (**C16**)  
*Lonzarich, V., Colombari, S., Del Terra, L., De Angelis, E., Navarini, L. (Italy)*
- 11:15 Characterization of animal preference to Arabica coffee varieties and flavor profile on domesticated "Luwak" (Paradoxorus hermaphroditus) (**C10**)  
*Yusianto, Ismayadi, C., Saryono, A., Nugroho, D., Mawardi, S. (Indonesia)*
- 11:30 1H-NMR profiling of green and roasted coffee extracts: classification of Colombian coffees (**C15**)  
*Arana, V. A., Medina, J., Alarcon, R., Moreno, E., Heintz, L., Schäfer, H., Wist, J. (Colombia)*
- 11:45 Milk modifies coffee sensory properties and reveals unexpected notes (**C14**)  
*Puget, S., Dugas, V., Pineau, N. Folmer, B. (Switzerland)*
- 12:00 Lunch. Sponsored by: 

## Coffee Chemistry

**Chair persons: J. Melrose (UK) & C. Yeretzian (Switzerland)**

- 13:00 Oleosomes in defective Arabica beans (**C7**)  
*Crisafulli, P., Silizio, F., Pallavicini, A., Navarini, L., Illy, A. (Italy)*
- 13:15 Identification of phenolic and carotenoid compounds in coffee (*Coffea Arabica*) pulp, peel and mucilage by HPLC electrospray ionization mass spectrometry (**C9**)  
*Viñas, M., Kramer, M., Schweiggert, R. M., Guevara, E., Carle, R., Jimenez, V.M., Esquivel, P. (Costa Rica)*
- 13:30 Beta-Sitosterol — A parameter for studying the coffee proportion in coffee drinks (**C2**)  
*Buchmann, S., Weiβ, G., Kölling-Speer, I., Speer, K. (Germany)*
- 13:45 Potential of diffuse reflectance Fourier transform infrared spectroscopy (drifts) for detection of adulteration in roasted coffees (**C6**)  
*Reis, N., Franca, A.S., Oliveira, L.S. (Brazil)*
- 14:00 Pursuing green coffee geographic origin discrimination through relations between isotopes and environmental factors (ISOGEOCOFFEE project) (**C8**)  
*Rodrigues, C., Maia, R., Pimpao, M., Brunner, M., Bowen, G., Hildebrandt, P., Ramalho, J. C., Gautz, L., Prohaska, T., Måguas, C. (Portugal)*
- 14:15 Detection of corn and barley as adulterants in roasted coffee using real-time PCR. (**C19**)  
*Ferreira, T., Oliveira, E., Oliveira, T., Lima, I., Vitório, F., Farah, A. (Brazil)*
- 14:30 Untargeted metabolomics: a powerful tool in coffee research (**C4**)  
*De Vos, R. C.H., Mumm, R., Borém, F. M., Blank, I., Pollien, P., Lindinger, C., Hageman, J.A., Hall, R. D. /The Netherlands)*
- 14:45 Coffee break. Sponsored by: 

## Coffee chemistry - Processing

**Chair persons: L. Navarini (Italy) & S. Mawardi (Indonesia)**

- 15:15 Efficient digestion of the coffee bean cell wall using food-processing cellulase and microorganisms (**C12**)  
*Kasai, N., Sakamoto, T. (Japan)*
- 15:30 Identification of the fungal microflora of coffee beans from different origins and evaluation of different decontamination concepts (**C11**)  
*Waters, D. M., Moroni, A., Arendt, E. K. (Ireland)*
- 15:45 Dynamics and biodiversity of microorganisms (fungi, bacteria, yeast) by PCR-DGGE, linked to origin and post harvest treatments on coffee beans (**C17**)  
*Durand, N., El Sheikha, A., Suarez-Quiroz, M-L., Gonzalez-Rios, O., Meile, J-C., Nganou Donkeng, N., Galindo-Schorr, S., Fontana, A., Pavon, C., Estrada, E., Macia, I., Martinez, A., Montet, D. (France)*
- 16:00 Study of green coffee processing and brewing variability across species, origins, grades and time (**P3**)  
*Arman, E., Guilmeneau, F., Melrose, J. (UK)*
- 16:15 The effect of effective microorganism (EM) for cleaning effluent from coffee washing mills in Ethiopia (**P2**)  
*Tesfu Kebede (Ethiopia)*
- 16:30 Enhancement Arabica coffee flavor by involving biological agents during fermentation process (**P4**)  
*Yusianto, Nugroho, D., Mawardi, S. (Indonesia)*
- 16:45 Identification of biochemical and physiological markers related to green coffee under storage (**P6**)  
*Lambot, C., Husson, J., Bedon, L., Goulois, E., Privat I., Michaux, S., Broun, P. (France)*
- 17:00 Drying rate and quality of natural coffee (**P5**)  
*Borém, F. M., Isquierdo, E.P., Taveira, J. H. S., Giomo, G., Alves, G. E., Oliveira, Pedro D., Ribeiro, D. E. (Brazil)*
- 17:15 Gasification of by-products from the coffee processing for power generation (**P1**)  
*Montero, E., Chacon, R. (Costa Rica)*
- 17:30 End of the session

## **Wednesday November 14, 2012**

### **Plant Genomics & Genetics**

**Chair persons : M. Cristancho (Colombia) & P. Broun (France)**

- 8:30 From genomics to varietal improvement in coffee (**B1**)  
*Lashermes, P. (France)*
- 9:15 Differential expression of WRKY transcriptional factors in endosperm tissues during stress and ontogeny of fruits of Coffea canephora with respect to caffeine biosynthesis (**B2**)  
*Giridhar, P., Avinash, K., Simmi, P.S., Ravishankar, G.A. (India)*
- 9:30 Ancestral synteny shared between distantly-related plant species from the Asterid and Rosid clades. (**B4**)  
*Guyot, R., Lefebvre-Pautigny, F., Tranchant, C., Rigoreau, M., Poncet, V., Hamon, P., Leroy, T., Hamon, S., Crouzillat, D., De Kochko, A. (France)*
- 9:45 Interaction between coffee plants and the insect coffee berry borer, Hypothememus hampei (**A12**)  
*Gongora, C., Macea, E., Castro, A. M., Idarraga, S., Cristancho, M., Benavides, P., Gaitan, A., Galbraith, D., Vanier, C. (Colombie)*
- 10:00 Integration of genetic linkage maps for Coffea Arabica (**B6**)  
*Caixeta, E. T., Pestana, K. N., Salgado, C. C., Capucho, A. S., Queiroz, T. F.N., Porto, B. N., Cruz, C. D., Maciel-Zambolim, E., Zambolim, L., Sakiyama, N.S. (Brazil)*
- 10:15 International high density coffee Robusta genetic map (**B5**)  
*Crouzillat, D., Rigoreau, M., Priyono, Ming, R., Lashermes, P. (France)*
- 10:30 Coffee break.

**Chair persons : A. Andrade (Brazil) & A. de Kochko (France)**

- 11:00 Coffee cysteine proteinases and related inhibitors with high expression during grain maturation and germination (**B7**)  
*Lepelley, M., Ben Amor, M., Martineau, N., Cheminade, G., Berry, V., McCarthy, J. (France)*
- 11:15 High-throughput sequencing of cDNA shows that cv. Rubi and IAPAR59 of Coffea arabica have different molecular response to water privation (**B8**)  
*Vidal, R. O., Alekcevetch, J. C., Leroy, T., De Bellis, F., Pot, D., Rodrigues, G. C., Carazzolle M. F., Pereira, G. A.G., Andrade, A. C., Marraccini, P. (Brazil)*
- 11:30 Geographical gradients in the genome size variation of wild coffee trees (Coffea) native to Africa and Indian ocean islands (**B9**)  
*Razafinarivo, N.J., Rakotomalala, J.-J., Brown, S., Bourge, M., Hamon, S., De Kochko, A., Poncet, V., Dubreuil-Tranchant, C., COUTURON, E., Guyot, R., Hamon, P. (Madagascar)*

**Chair persons : B. Bertrand (France) & V. Varzea (Portugal)**

11:45      **Short Oral Presentations:**

An inhibitor from Lupinus bogotensis seeds effective against aspartic proteases from Hypothenemus hampei (**PB264**)

*Molina, D. M., Bastos, S., Quintero, M., Patiño, L., Blanco-Labra, A. (Colombia)*

Analysis of the expression pattern of miRNAs, by stem-loop RT-PCR, in coffee species with different ploidy levels (**PB265**)

*Chalfun-Junior, A., Chaves, S. S., Silva, G., Valentim, F. L., Ferrara-Barbosa, B. C., Paiva, L. V., Andrade, A. C. (Brazil)*

Restructured sampling plan enables the characterization of more virulence genes of Hemileia vastatrix in Kenya (**PA305**)

*Gichuru, E. K., Ithiru, J. M., Silva, M. C., Pereira, A. P., Várzea, V. M. P. (Kenya)*

New cytological and molecular data on coffee- Colletotrichum kahawae interactions (**PB266**)

*Loureiro, A., Figueiredo, A., Batista, D., Baraldi, T., Várzea, V., Azinheira, H. G., Talhinas, P., Pais, M. S., Gichuru, E. K., Silva, M. do C. (Portugal)*

Relative influence of plot and landscape scale factors on coffee berry borer abundance: a variation partitioning hierarchical approach (**PA307**)

*Vilchez, S., Romero-Gurdian, A., Cruz-Cueilar, H. F., Declerck, F., Avelino, J. (Costa Rica)*

Identification of the vulnerability of coffee farmers' livelihoods and development of adaptation strategies to climate change in Mesoamerican (**PA310**)

*Baca, M., Läderach, P., Ovalle, O., Zelaya, C., Ocón, S., Gómez, L., García, S. (Nicaragua)*

12:30

Lunch. Sponsored by:



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**Sustainability– Coffee quality**

**Chair persons: P. Läderach (Nicaragua) & C. Cerri (Brazil)**

13:30      The changing climate for sustainable coffee (**A1**)  
*Baker, P. (UK)*

14:15      Integrated climate change impact modeling of the coffee sector indicates migration of producing regions and pressure on ecosystems (**A2**)  
*Bunn, C., Mosnier, A., Ovalle-Rivera, O., Läderach, P., Obersteiner, M. (Colombia)*

14:30      Global impact of climate change on coffee suitability (**A3**)  
*Ovalle-Rivera, O., Läderach, P., Bunn, C. (Colombia)*

- 14:45 Greenhouse gases emissions of green coffee production in the state of Minas Gerais, Brazil: measurement and mitigation (**A4**)  
*Moreira, C. S., Alves, P. A., Castigioni, B. A., Raucci, G. S., Galdos, M. V., Carvalho, J. L. N., Cerri, C. E. P., Cerri, C. C., Teixeira, A. A., D'Alessandro, C. S., Candiano, C., Reis, M., Celi, G. (Brazil)*
- 15:00 Measuring the carbon footprint in coffee production system (**A5**)  
*Arias, J. J., Riaño, N. M., Rojas, J. M., Gonzalez, L. A., Alzate, D., Obando, D., Ocampo, J. L., Galvis, C., Samper, L.F. (Colombia)*
- 15:15 Vietnam coffee sector review and perspective (**A6**)  
*Tran Thi Quynh Chi (Vietnam)*
- 15:30 Coffee break.

**Chair persons : G.Oliveiro Guerreiro Filho (Brazil) & E. Alpizar (Costa Rica)**

- 16:00 Assisted-selection of naturally caffeine-free cultivar: SNPs characterization (**B3**)  
*Favoretto, P., Moraes, P. F., Giatti, G., Tavares, A.G., Leal, R. R., Silvarolla, B. M., Maluf, M. P., Oliveira-Filho, G. (Brazil)*
- 16:15 Climatic factors directly impact the biochemical composition and the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality (**A8**)  
*Bertrand, B., Boulanger, R., Dussert, S., Laffargue, A., Ribeyre, F., Berthiot, L., Descroix, F., Joët, T. (France)*
- 16:30 Environmental and social standards: their impact on farm and coop performance in Nicaragua (**A24**)  
*Haggard, J., Hocdé, H., Le Coq, J.F., Soto, G., Jerez, R., Mendoza, R., Preza, M. (Nicaragua)*
- 16:45 Development and release of coffee berry disease resistant varieties to specialty coffee producing regions in Ethiopia (**A7**)  
*Chala, J., Girma, A., Demelash, T., Arega, Z., Seife, B. (Ethiopia)*
- 17:00 **Posters Session: Biotechnology & Agronomy**
- 18:00 End of the session

## Thursday November 15, 2012

### Pests & Diseases

**Chair persons : M. Ceu da Silva (Portugal) & A. Gaitan (Colombia)**

- 8:30 Coffee pests in a changing world (**A11**)  
*Jaramillo, J. (Kenya)*
- 9:15 Genomics to overcome climate change in the control of the coffee berry borer,  
*Hypothenemus hampei*, in Colombia (**B10**)  
*Benavides, P., Constantino, L. M., Navarro, L., Acevedo, F. E., Nuñez, J., Hernandez, E., Gil, Z., Barrera, C., Berrio, A., Zapata, L., Martinez, H., Perez, L. G., Montoya, E. C., Giraldo, W., Cristancho, M., Gaitan, A., O'Brochta, D., Aluvihare, C., Harrell, R., Lima, E. (Colombia)*
- 9:30 Pyramiding of rust resistance genes as an approach for durable resistance in Arabica  
(*Coffea arabica*) - Indian experience (**B14**)  
*Prakash, N.S., Yashoda, M.H., Suresh, N., Mishra, M.K., Hanumantha, B.T., Anil Kumar, Srinivasan, C.S. and Jayarama (India)*
- 9:45 Large-escale expression of genes related to phytoalexins, phenols, flavonoids and lignin biosynthesis in coffee plants infested with leaf-miner (**B11**)  
*Martinati, J. C., Cardoso, D. C., Vidal, R. O., Carazzolle, M. F., Giachetto, P. F., Padilha, L., Guerreiro-Filho, O., Maluf, M. P. (Brazil)*
- 10:00 Resistance to leaf miner in coffees carrying *Coffea racemosa* genes derived from backcrosses with *Coffea arabica* genotypes (**A22**)  
*Sera, T., Sera, G. H., Andreazi, E., Mariucci, V., Shigueoka, L. H., Carvalho, F. G., Gardiano, C. G. (Brazil)*
- 10:15 New record and outbreaks of bacterial blight of coffee (*Pseudomonas syringae*) in Southern Ethiopia: impact of climate change scenarios (**A14**)  
*Adugna, G., Jefuka, C., Abate, S., Teferi, D. (Ethiopia)*
- 10:30 Coffee break. Sponsored by:
- 
- Science For A Better Life

**Chair persons : G. Adugna (Ethiopia) & N.S. Prakash (India)**

- 11:00 Application of coffee rust genomics to the understanding of its evolution (**B12**)  
*Cristancho, M., Giraldo, W., Botero, D., Tabima, J., Ortiz, D., Peralta, A., Gaitán, Á., Restrepo, S., Riaño, D. (Colombia)*
- 11:15 Arabica coffee production in the Yunan province of China (**A15**)  
*Zhang, H., Li, J., Zhou, H., Chen, Z., Pereira, A. P., Silva, M.C., Várzea, V.M.P. (Portugal)*
- 11:30 Susceptibility assessment of (*Coffea* spp) coffee genotype to the *Mycena citricolor* fungus and determination of candidate defense genes (**B13**)  
*Echeverría-Beirute, F. (Costa Rica)*

**Chair persons : H. van der Vossen (The Netherlands) & J. Teri (Tanzania)**

11:45      *Short oral presentations :*

Introgression of the rust resistance gene sh3 into Colombian Elite Catimors through a marker assisted selection strategy (**PA306**)

*Herrera, J. C., Hurtado, I., Gonzales, L., Cortina, H. (Colombia)*

Strengthening producer organizations to speed up the multiplication of improved hybrid coffee varieties in Tanzania (**PA309**)

*Magesa, J. M., Mushi, I. K., Shayo, G., Ng'homma, N. M., Mdemu, S., Tarimo, E., Teri, J. M. (Tanzania)*

Participatory breeding on Arabica coffee to obtain superior local variety in order to support specialty origin coffee development in Indonesia (**PA311**)

*Hulupi, R., Nugroho, D., Mawardi, S., Aman Al, M. (Indonesia)*

Impact of long-term increased ambient CO<sub>2</sub> on Coffea arabica and C. canephora photosynthetic functioning (**PB263**)

*Ramalho, J. C., Rodrigues, A. P., Semedo, J., Pais, I. P., Batista-Santos, P., Goulao, L. F., Fortunato, A. S., Palos, I. M., Maia, I., Scotti-Campos, P., Damatta, F. M., Lidon, F. C. (Portugal)*

12:30      *Lunch. Sponsored by:*


**Coffee Agronomy. Agro-ecology & Breeding**
**Chair persons: G. Armando Garcia (Guatemala) & J. Avelino (Costa Rica)**

13:30      Lessons from CAFNET: an international project documenting environmental services of coffee agroforestry in Central America, India and East Africa (**A16**)

*Vaast, P. (France)*

14:15      Improving water productivity in Arabica coffee (minireview) (**A17**)

*Van Der Vossen, H.A.M. (The Netherlands)*

14:30      Modelling vegetative growth and architecture of Coffea arabica cultivars under water stress (**A18**)

*Dauzat, J., Griffon, S., Marraccini, P., Rodriguez, G. (Brazil)*

14:45      An assessment of the contribution of the coffee growing region of Colombia to the conservation of birds of conservation concern (**A19**)

*Velásquez, J. I., Botero, J. E., Renjifo, L. M. (Colombia)*

15:00      Shade has antagonistic effects on coffee berry borer (**A20**)

*Sanchez, E., Dufour, B., Olivas, A., Virginio Filho, E. De M., Avelino, J. (Panama)*

15:15      Shade is conducive to coffee rust as compared to full sun exposure under standardized fruit load conditions in a sub-optimal zone for coffee in Costa Rica (**A21**)

*Lopez-Bravo, D. F., Virginio Filho, E. d e M., Avelino, J. (Costa Rica)*

15:30      Coffee break. Sponsored by:



**Chair persons : T. Schilling (USA) & E. Gichuru (Kenya)**

- 16:00 Successful case studies of adopting improved coffee varieties in Tanzania (**A10**)  
*Kilambo, D., Mtenga, D., Ng'homma, N., Ngomuo, R., Teri, J. (Tanzania)*
- 16:15 Rust resistance in Arabica coffee cultivars in Paraná, Brazil (**A13**)  
Sera, G. H., Sera, T., Del Grossi, L., Fonseca, I. C. De B., Shigueoka, L. H., Andreazi, E.,  
*Carvalho, F. G., Gardiano, C. G., Mariucci, V. (Brazil)*
- 16:30 A current perspective on climate variations and their effects on coffee disease management in Colombia (**A23**)  
*Rivillas, C., Cristancho, M., Gaitan, A. (Colombia)*
- 16:45 Coffee breeding in Kenya: achievements, challenges and current focus (**A9**)  
*Gichimu, B.M. (Kenya)*
- 17:00 End of the session

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**Friday November 16, 2012**

7:00

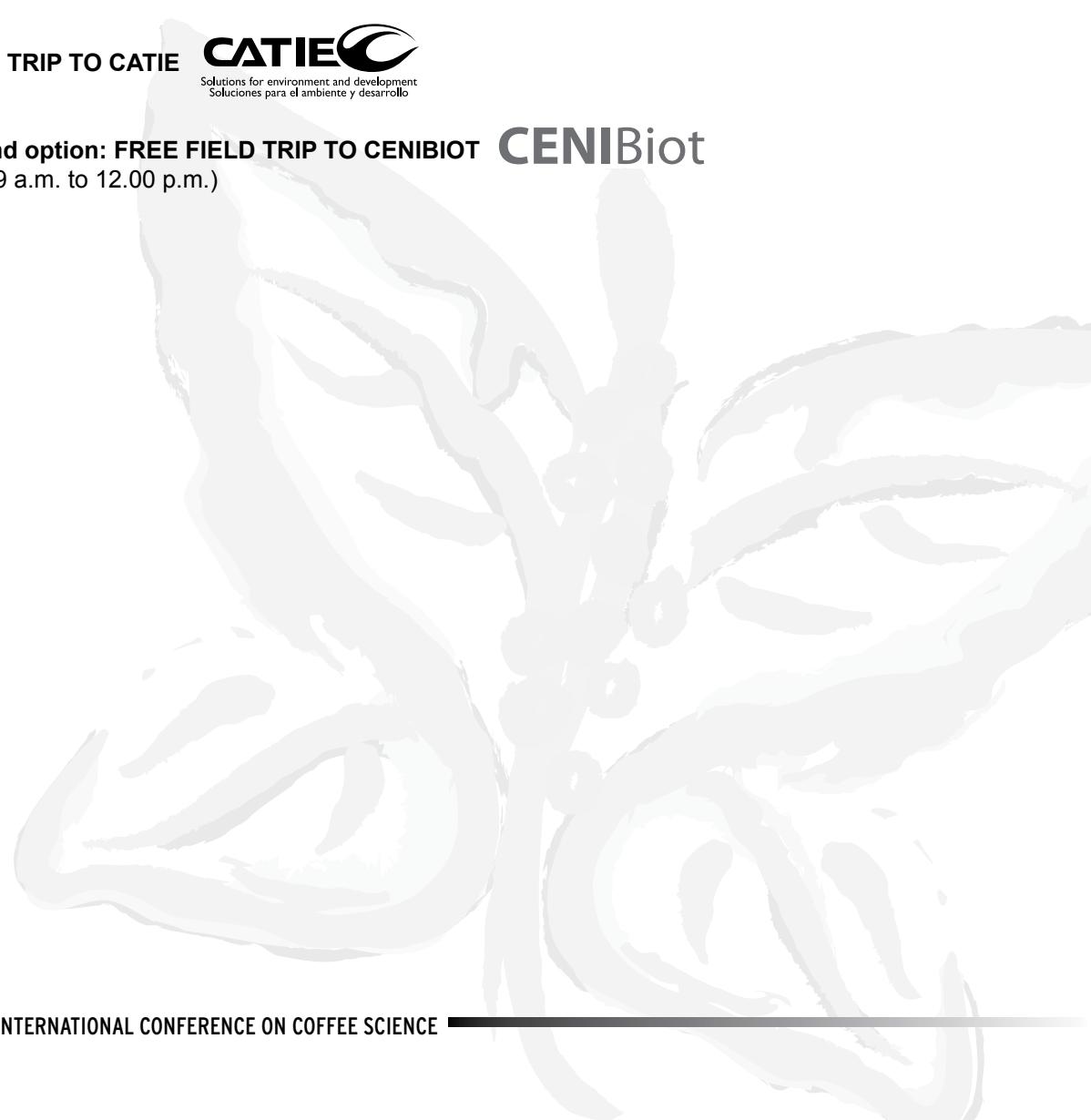
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9:00

**Second option: FREE FIELD TRIP TO CENIBIOT**  
(from 9 a.m. to 12.00 p.m.)

**CENIBiot**





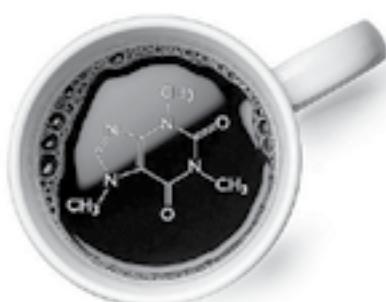


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## ORAL SESSIONS

**Monday November 12, 2012**



## H1

# COFFEE AND CANCER: A BENEFIT-RISK EVALUATION OF THE EXPERIMENTAL AND EPIDEMIOLOGICAL EVIDENCE

**NEHLIG, Astrid\*** and **COUGHLIN, James R.\*\***

\*INSERM U 666, Faculty of Medicine, Strasbourg, France, \*\*Coughlin & Associates: Consultants in Food/Nutritional/Chemical Toxicology and Safety, Aliso Viejo, CA USA.

Animal carcinogens found in heated foods and beverages have been a significant health concern since the 1970's, when trace levels of these compounds were discovered in many foods. Many of these compounds have been studied in the U.S. National Toxicology Program's (NTP) carcinogen bioassays in rats and mice as well as in the European Union's HEATOX Project, including acrylamide, furan and 4-methylimidazole (4-MEI), all of which have been found in roasted coffee as a result of the Maillard Browning Reaction (MBR). Perhaps the most prominent animal carcinogen in coffee is acrylamide, but there is now extensive epidemiologic evidence indicating that it is not a human dietary carcinogen. Furan, a rodent liver carcinogen, is also well-known constituent in coffee, and coffee is known to be the primary dietary source of furan. But paradoxically, coffee consumption actually reduces the risk of human liver cancer, the target organ for furan. And 4-MEI has been shown to induce only mouse lung tumors in chronic testing, while in the same NTP bioassay it reduced the incidence of tumors in several organs of the rat.

Currently there is little human epidemiologic evidence linking these trace level animal carcinogens in coffee with the risk of human disease, including cancer. The health benefits of a food such as coffee, including the effects of many health-protective, naturally occurring compounds (e.g., chlorogenic acids) and those produced by heat in the MBR (e.g., melanoidins), are often neglected by public health and regulatory authorities when assessing the overall safety of a food. In fact, coffee consumption has actually been shown to reduce the risk of several human cancers while not increasing cancer risk in other organs systems, in spite of the fact that coffee contains trace levels of many animal carcinogens. While it is obviously important to evaluate the toxicological risks of individual heat-induced carcinogens in foods including coffee, it is equally important to fully evaluate the safety of whole foods containing these carcinogens using a combination of modern clinical, toxicological, nutritional and epidemiological techniques using a benefit-risk evaluation of the whole food.

## References:

- [1] Arab L. Epidemiologic evidence on coffee and cancer. *Nutr. Cancer* **2010**, *62*, 271–283.
- [2] European Food Safety Authority (EFSA) Scientific Committee. Scientific Opinion: Guidance on human health risk-benefit assessment of foods. *EFSA Journal* **2010**, *8*(7), 1673.
- [3] HEATOX Project. Heat-generated food toxicants: identification, characterisation and risk minimisation.  
<http://heatox.org/>

## H2

### CAFFEINE AND AGE-RELATED COGNITIVE DECLINE

**RITCHIE, Karen**

*INSERM U 888, Montpellier, France; e-mail: karen.ritchie@inserm.fr*

Caffeine consumption has long been associated with enhancement of mood and cognitive functions, notably learning, memory and speed of information processing.

We examine the epidemiological evidence for a causal relationship between caffeine consumption and cognitive deterioration in the elderly. In a population study of 641 elderly persons we examined cognitive functioning, caffeine consumption, magnetic resonance imaging volumetrics and other factors known to affect cognitive performance. Our findings demonstrate the association between caffeine consumption and lower cognitive change over time to be statistically significant for women only, taking into account multiple confounders, to be dose-dependent and temporally related (caffeine consumption precedes cognitive change). Mean log transformed white matter lesion/cranial volume ratios were found to be significantly lower in women consuming more than 3 units of caffeine per day after adjustment for age. This observation is coherent with biological assumptions that caffeine through adenosine is linked to amyloid accumulation and subsequently white matter lesion formation. We also explore the possibility that this association may be modulated by diabetes risk factors.

## H3

### DOES COFFEE INTAKE REDUCE TYPE 2 DIABETES MELLITUS RISK?

**PIMENTEL, Gustavo Duarte**

*Department of Internal Medicine. State University of Campinas (UNICAMP) – Brazil*

Historically, in the middle of 15th century, the appearance of coffee was reported, probably in Africa. At this time, studies involving coffee consumption did not exist. On the other hand, with the advent of studies relating to the mechanisms that modulate obesity consequences, some researchers observed that coffee is associated with low incidence of type 2 diabetes mellitus risk. Likewise, the discovery of physiological and molecular advances for the treatment of patients with obesity and type 2 diabetes mellitus have been greatly appreciated by health professionals, such as nutritionists and physicians. Thus, same researchers found that a range of components may be responsible for this association, such as chlorogenic acid, caffeine, theophylline, theobromine and minerals, such as potassium and magnesium; on the other hand, these effects may occur with the consumption of both decaffeinated and caffeinated coffee. In summary, this lecture highlights the relationship between coffee and reduction of type 2 diabetes mellitus risk.

## H4

NEUROPROTECTIVE EFFECT OF COFFEE  
IN PARKINSON DISEASE.**COSTA, J.**

*Laboratory of Clinical Pharmacology and Therapeutics. Faculty of Medicine. University of Lisbon. Portugal.  
Neuromuscular Unit. Institute of Molecular Medicine. Lisbon. Portugal.*

The possible neuroprotective role of coffee is an old discussion in the medical literature. Many observational studies have suggested that coffee protects against the development of Parkinson Disease and Alzheimer Disease. Furthermore, a few studies reported that coffee may even delay disease progression, although data is more sparse and conflicting.

From a physiological point of view, it is assumed that caffeine is most probably the major coffee component responsible for the neuroprotective effects of coffee. In fact, an epidemiological negative association has also been reported for other non-coffee sources of caffeine, such as tea, but not for decaffeinated coffee. However, one should keep in mind that coffee is a complex chemical mixture reported to contain more than a thousand different chemicals. Thus, the possibility exists that other components of coffee (or tea) may also play a role. With respect to Parkinson Disease (PD), there is a plausible physiological mechanism based on the pharmacological actions of caffeine for the putative inverse association between coffee drinking and PD. Caffeine (1,3,7-trimethylxanthine) and its major metabolite, paraxanthine (1,7-dimethylxanthine), are nonselective antagonists of the adenosine A2A receptors. The expression of these receptors in the brain is particularly prominent in the striatum, which is the target of the dopaminergic neurons that degenerate in PD. Neurotoxicity models in animal studies have been shown to be attenuated by caffeine, which is capable of preventing apoptotic cell death by interfering with multiple molecular events.

A recent meta-analysis of 26 observational studies (case-control, nested case-control and cohort studies) found a 25% reduction in risk of PD among caffeine consumers (95% confidence interval: 18% to 32%). The results also indicate a linear dose-response relation, with higher intakes of caffeine being associated with a lower risk of PD. Although the magnitude of these results, as well as their relatively low heterogeneity, strongly suggests that there is a true strong inverse association between coffee consumption and the risk of PD, a word of caution is needed because epidemiological studies cannot show causal relationships. Furthermore, conflicting results exist about the protective role of caffeine on the progression of the disease itself.

Several issues remain uncertain regarding the inverse association between caffeine intake and the risk of PD, in particular the different individual susceptibility. Differences between men and women have been interpreted as due to postmenopausal hormonal replacement therapy. More recent, the role of genetic polymorphisms in ADORA2A (adenosine receptor A2A; the major receptor activity of caffeine in the brain) and CYP1A2 (cytochrome P450 1A2; the major rate-limiting step of caffeine metabolism) has been addressed to explore physiological explanations for the individual variability and between-studies variability in the neuroprotective effect of caffeine. Gene-environment interactions could, at least partially, explain the different PD susceptibility among coffee drinkers.

## H5

### COFFEE AND COFFEE CONSTITUENTS FOR PROMOTING BODY WEIGHT-MAINTENANCE IN HEALTHY SUBJECTS

**SOMOZA, Veronika\***, **RIEDEL, Annett\***

\**Department of Nutritional and Physiological Chemistry, University of Vienna, Vienna, Austria*

Epidemiological studies provide evidence that moderate coffee consumption is associated with a lower incidence of metabolic syndrome. Obesity is one of the major risk factors of metabolic syndrome, which is becoming more common due to a rise in obesity rates among adults. Since it is possible to prevent or delay metabolic syndrome by maintaining a healthy body weight, there is growing interest in foods that may help to control energy intake and/or mimic energy expenditure by, e.g., inducing mechanisms of satiety or thermogenesis. Coffee, when consumed in moderate amounts of 3 – 4 cups per day, has been demonstrated to decrease the daily energy intake and to stimulate mechanisms of satiety in healthy volunteers. Coffee components such as caffeine and chlorogenic acids have been shown to induce mechanisms of thermogenesis in cells in culture. This paper will present an overview and novel insights into the identification of coffee components that act on these mechanisms.

## H6

### BLANCHING AND AIR DRYING EFFECT ON ANTIOXIDANT CAPACITY AND FIBER CONTENT OF PROCESSED COFFEE PULP FOR HUMAN CONSUMPTION

**CUBERO, Elba\*\*, BOLAÑOS, Carolina\*\*, BONILLA, Ana Ruth\*, Vargas, Pedro\*\***

\**University of Costa Rica, Food Technology National Center, San Pedro de Montes de Oca, Costa Rica, \*\*University of Costa Rica, Food Technology Department, San Pedro de Montes de Oca, Costa Rica.*

The effect of blanching and drying of coffee pulp on the antioxidant capacity, fiber, total polyphenols, anthocyanins, chlorogenic acid and caffeine content and its potential as a dried ingredient for human consumption was evaluated.

Organic coffee pulp was collected immediately after crushing. Six different treatments combining acidification, blanching and drying were applied: coffee pulp without treatment, acidified coffee pulp without blanching and drying, non acidified blanched and dried at 55 and at 70 ° C, acidified pulp and dried at 55 and at 70 ° C. These samples were analyzed for antioxidant capacity, and results showed that blanched samples had higher antioxidant capacity than the unblanched ( $p<0.0001$ ) ones and that drying temperature had no significant effect on the antioxidant capacity. Coffee pulp that was acidified, blanched and dried at 70 °C or at 55 °C presented the highest antioxidant capacity, dry basis, values (487 y 492 umolTE/mg dry basis sample at 70 °C and at 55 °C).

Subsequently, compounds with antioxidant properties such as total polyphenols, total anthocyanins, chlorogenic acid and caffeine were compared in coffee pulp samples without treatment, only acidified and acidified, blanched and dried at 55 and at 70 ° C. Results showed that total polyphenol content was not affected by treatment ( $p > 0.05$ ). Total anthocyanins, reported as cyanidin 3-rutinoside equivalent, were higher for the treated samples ( $p = 0.001$ ), than the untreated ones. However total anthocyanin content was affected by drying temperature, as a decrease in the content of this compound at higher temperature occurred ( $p= 0.048$ ).

Chlorogenic acid and caffeine content was not changed by the treatments ( $p > 0.05$ )

Fiber content of non treated samples and treated (acidified, blanched and dried at 70 ° C) samples did not show significant differences ( $p > 0.05$ )

Finally, a study of product concept to identify potential uses of treated coffee pulp was carried out. Four potential products (biscuits, fizzy drinks, condiments and tea) were evaluated in such a way that dried coffee pulp could be applied as an ingredient. Consumers concept study showed that the dried coffee pulp could be used in any of the evaluated products.

**H7**

## COFFEE POLYPHENOLS PROTECT PLASMA AND LDL FROM POSTPRANDIAL OXIDATIVE MODIFICATION IN HUMAN

**SIROTA, Roman<sup>1</sup>, GORELIK, Shlomit<sup>1</sup>, HARRIS, Raviv<sup>1</sup>, KOHEN, Ron<sup>1</sup>, KANNER, Joseph<sup>2\*</sup>**

<sup>1</sup>The Institute of Drug Research, Faculty of Medicine, Hebrew University of Jerusalem, <sup>2</sup>Department of Food Science, ARO, Volcani Center, Bet Dagan, ISRAEL.

The association between modified- LDL and atherogenesis is now firmly established. Modified -LDL is involved in atherogenesis, but their origin in-vivo is uncertain. High fat foods and red-meat not only affect endogenous lipoprotein production and catabolism, but also lead to postprandial exposure of arteries to cytotoxic compounds inducing atherogenesis.

Coffee is one of the most popular beverages in the world supplying the most significant portion of daily intake of dietary antioxidants, mainly polyphenols. The results showed that heated red-meat is further oxidized in stomach medium generating hydroperoxides, reactive carbonyls and other advanced lipid oxidation end-products (ALE). Roasted-ground coffee was found to inhibit this oxidation and be 2 to 5 fold more efficient antioxidant than instant freeze-dried soluble coffee. A cup of roasted-ground coffee of 168 ml could inhibit lipid peroxidation generated in stomach medium by 200g of red-meat. The results revealed a relatively rapid accumulation of malondialdehyde (MDA) in human plasma and LDL of volunteers after a meal of red-meat cutlets (250 g). Roasted-ground coffee beverage (200ml) consumed by 10 volunteers during a meal of red-meat cutlets inhibited plasma MDA absorption by 80% and 50%, 2h and 4h after the meal, respectively. Our results emphasized the importance of the stomach as the main organ by which food oxidation and antioxidation processes take place and affect absorption of ALE into the blood circulation. The results obtained in *in-vitro* system were found to be predictive for MDA plasma modification *in-vivo* in human. The control of lipid peroxidation of foods in the stomach by dietary specific antioxidants such those found in coffee seems to be a critical site and step for preventing postprandial oxidative stress and cardiovascular diseases in humans. Our biochemical and clinical studies explain the recent epidemiological data suggesting protective effects of coffee on cardiovascular diseases.

## H8

DEVELOPMENT OF ACRYLAMIDE-FREE "READY-TO-DRINK"  
COFFEE BY *ASPERGILLUS ORYZAE*

IWAI, Kazuya\*, FUKUNAGA, Taiji\*, NARITA, Yusaku\*, NAKAGIRI, Osamu\*,

TSUBOI, Hirokazu\*\*, BOGAKI, Takayuki\*\*, SANO, Motoaki\*\*\*, OZEKI, Kenji\*\*\*

\*R&D center, UCC Ueshima Coffee, Co., Ltd., Osaka, Japan. \*\*General Research Laboratory, Ozeki Corp., Hyogo, Japan. \*\*\*Genome Biotechnology Laboratory, Kanazawa Institute of Technology, Ishikawa, Japan.

In 2010, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) estimated that the average acrylamide (AA) exposure was 0.001 and 0.004 mg/kg bw per day and the MOE (margin of exposure) value was 200 and 50 for the general population and for consumers with a high dietary intake of coffee, respectively. The amounts of AA formed during the first few minutes of the roasting process is 3.8 µg/g in Robusta (*Coffea canephora*) coffee and 0.5 µg/g in Arabica (*Coffea arabica*) coffee [1]. The daily dietary intake of AA is high in countries and individuals with a high consumption of coffee. These findings have led to a worldwide concern, thereby encouraging research activities to investigate the formation and mitigation of AA in foods.

In 2009, Wakaizumi et al [2] reported that *Aspergillus oryzae*, called "National fungus", a filamentous fungus or a mold, used to saccharify starch from rice into sugars in the sake brewing industry can reduce AA by AA-degrading enzymes (amidase: EC 3.5.1.4) present in their mycelia. The main purpose of this study was to confirm the acrylamide-reducing effect of *A. oryzae* during the production of ready-to-drink coffee on a laboratory scale and to evaluate the properties of this treated coffee liquid. First, we inoculated the *A. oryzae* in YPD medium (pH 6.5, 30°C, 100 rpm for 3 days). After pre-incubation, we evaluated the amidase and AA-degrading activity of the mycelia in the extracted coffee liquid.

This strain degraded nearly all AA in a 10 ppm-AA aqueous solution at 6 h, and this effect was also observed in a sample of commercially extracted coffee.

Caffeine, chlorogenic acid, and organic acid (citric, quinic, malic, glycolic, lactic, acetic, and formic acids) contents in the treated coffee liquid tended to decrease compared with that in the control coffee liquid. Flavor analysis by GC-MS showed that the concentration of 1-propanol, ethyl acetate, 2-methyl-1-butanol, isobutyl alcohol, and isoamyl alcohol, which are constituent elements in fruits, flower, wine, and sake, were markedly increased in the treated coffee liquid compared with that in the control.

Moreover, the results of sensory tests by trained panels showed that the treated coffee had a fruity, sweet floral flavor. We hope that these data will help make "AA-free ready-to-drink coffee" a practical reality.

## REFERENCES

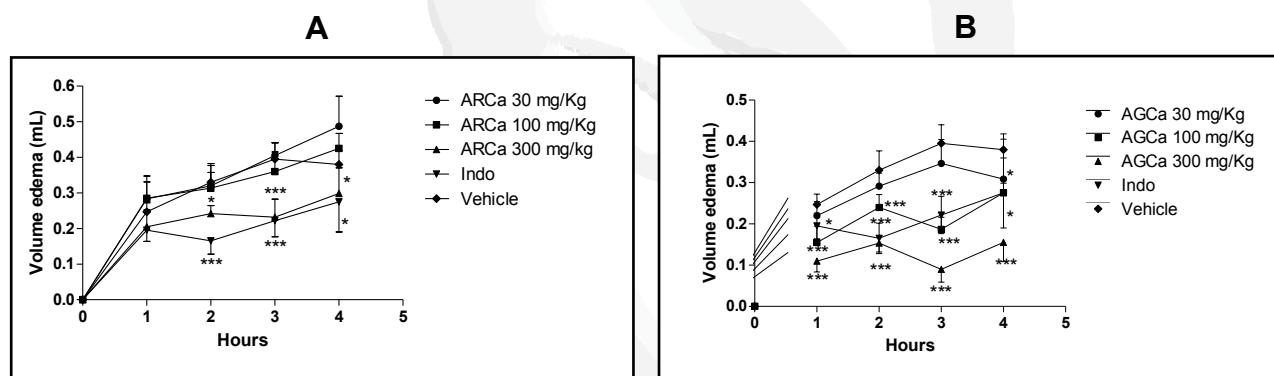
- [1] Bagdonaitė, K et al. Determinations of acrylamide during roasting of coffee. *J. Agric. Food Chem.* 2008, **56**, 6081-6086
- [2] Wakaizumi, M et al. Acrylamide degradation by filamentous fungi used in food and beverage industries. *J. Biosci. Bioeng.* 2009, **108**, 391-393

**H9**
**COFFEA ARABICA L.: ANTI-INFLAMMATORY  
ACTIVITY OF AQUEOUS EXTRACTS**

**MOREIRA, Maria Eliza de Castro\***, **PEREIRA, Rosemary Gualberto Fonseca Alvarenga\***, **DIAS, Danielle Ferreira\*\***, **GONTIJO, Vanessa Silva\*\*\***, **VILELA, Fabiana Cardoso\*\*\*\***, **MORAES, Gabriel de Oliveira Isaac\*\*\***, **GIUSTI-PAIVA, Alexandre \*\*\*\***, **DOS SANTOS, Marcelo Henrique\*\***

\*Department of Food Sciences of Federal University of Lavras, Lavras-MG, Brazil; \*\*Faculty of Pharmaceutical Sciences of Federal University of Alfenas-MG, Alfenas, Brazil; \*\*\*Institute of Exact Sciences of Federal University of Alfenas-MG, Alfenas, Brazil; \*\*\*\*Department of Biomedical Sciences of Federal University of Alfenas-MG, Alfenas, Brazil.

Coffee is consumed because of this desirable flavor taste. In recent years, both coffee and coffee constituents have been increasingly studied, with respect to both potentially beneficial and potentially adverse health effects. The aim of this work was to verify the anti-inflammatory and antioxidant effects of aqueous extracts of green (AGCa) and roasted (ARCa) coffee beans (*Coffea arabica* L.) in animal models and DPPH radical scavenging test, respectively. Formalin test, carrageenan-induced paw edema and peritonitis were used to investigate the anti-inflammatory activity of coffee extracts. The extracts were administrated per via orally in 30, 100 and 300 mg.Kg<sup>-1</sup>. In the formalin test, the doses extracts reduced the licking activity only in the late phase. The inhibitory values of edema at 3 h post-carrageenan were 41% for ARCa (Fig. A) for 300 mg/kg and 53 and 77% for 100 and 300 mg/kg of the extract AGCa (Fig. B).



The leukocyte recruitment into the peritoneal cavity was inhibited by the extracts (ARCa and AGCa). In antioxidant test, the AGCa and ARCa extracts showed IC<sub>50</sub> 2.93 and 1.84 µg/ml, and standards ascorbic acid and BHT of 9.07 and 7.62 µg/ml, respectively. These results indicate that these extracts exhibit anti-inflammatory and antioxidant properties due to potential of coffee-derived compounds.



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## ORAL SESSIONS

**Tuesday November 13, 2012**



C 21

THE MULTIPLE ROLE OF POLYPHENOL CHEMISTRY IN COFFEE  
ASSOCIATED WITH QUALITY ATTRIBUTES**BLANK, Imre, MORA, Federico, KERLER, Josef, and LELOUP, Valérie**

Nestle PTC Orbe, CH-1350 Orbe, Switzerland

Polyphenols such as chlorogenic acids (CGA, O-caffeoylelquinic acids) and related compounds are the main components of the phenolic fraction of green coffee beans, reaching levels up to 14 % on dry matter basis. The main groups of CGA found in green coffee beans include caffeoylelquinic acids, dicaffeoylelquinic acids, feruloylquinic acids, p-coumaroylquinic acids and mixed diesters of caffellic and ferulic acids with quinic acid. During coffee processing, CGA may be isomerized, hydrolyzed or degraded into low molecular weight compounds. The high temperatures of roasting also produce transformation of part of CGA into quinolactones and melanoidins. Thus, complex polyphenol chemistry occurs during thermal treatment of coffee.

Flavour and aroma compounds derive from multiple chemical reactions, including the Maillard reaction, caramelization, polyphenol degradation, polymerization, lipid oxidation and pyrolysis. Polyphenols lead on the one hand to the generation of guaiacols and cresols that contribute to coffee flavour. On the other hand, they are precursors of phenolic compounds that can trap thiols and thus induce aroma degradation, which can be a particular problem when coffee is stored as a canned or bottled beverage or as a liquid coffee concentrate. Coffee aroma staling is mainly due to the decrease of the coffee-like smelling compound 2-furfurylthiol trapped by the polyphenol degradation products di- and trihydroxybenzenes, and in particular hydroxyhydroquinone. This oxidative coupling reaction may also affect other odour-active thiols such as methanethiol that are present in freshly brewed coffee.

Coffee polyphenol derivatives are also significant contributors to bitterness, e.g. chlorogenic acid lactones and hydroxylated phenyllindanes. Bean roasting either can break these phenolic acids down to form di- and trihydroxybenzenes such as hydroxyhydroquinone or can epimerize and dehydrate the acids to give various lactones that may provide a pleasant, coffee-like bitter taste quality in light- to medium-roast coffee.

Coffee brew melanoidins certainly contribute to the well appreciated brown color of the beverage. Moreover, they have also recently been discussed as affecting foaming properties. Polymeric coffee melanoidins contain both hydrophilic and hydrophobic moieties. The hydrophilic parts are due to the proteinous moieties and negatively charged groups, while the hydrophobic parts are the result of polycondensation reactions by Maillard-type reactions, with polyphenols being involved. The combination of both hydrophilic and hydrophobic portions likely provides high foamability and foam stability to coffee. As roasting affects the melanoidin properties, it is expected that the roasting process will also influence the foaming properties of coffee brew.

Finally, coffee polyphenols have also a number of beneficial health properties related to their antioxidant activity. In the beverage, they slow down the Fenton reaction. Overall, it seems coffee polyphenols and their chemistry will likely influence cup quality. However, controlling the fate of polyphenols remains a challenging task due to their manifold implication in chemical reactions.

**C 1**
**DIFFERENTIATION OF THE ROBUSTA AND ARABICA VARIETIES BY ON-LINE ANALYSIS OF THE CHEMICAL SIGNATURE IN THE ROASTING-GAS INSIDE OF INDIVIDUAL COFFEE BEANS DURING ROASTING BY MICROPROBE-SAMPLING PHOTO-IONISATION MASS SPECTROMETRY**
**HERTZ, R., STREIBEL, T., GRABOWSKI, J., ZIMMERMANN, R.**

Joint Mass Spectrometry Centre of the University of Rostock, Analytical Chemistry, Rostock,/Germany and the Helmholtz Zentrum München, Institute of Ecological Chemistry, Neuherberg/Germany

Single-Photon Ionization and Resonance-Enhanced MultiPhoton Ionization Time-Of-Flight Mass Spectrometry (SPI-/REMPI-TOFMS) were applied for studying the coffee and cocoa roasting process. Both techniques are very sensitive. While REMPI is particularly sensitive and selective for fast on-line detection of aromatic molecules, SPI allows the acquisition of overview mass spectra consisting of all organic species. However, REMPI and SPI are both soft ionization methods, allowing the direct recording of the molecular ion profiles. REMPI-and SPI-TOFMS has been applied e.g. for on-line trace measurements aromatic hydrocarbons in industrial flue gases [1], for puff resolved monitoring of cigarette smoke [2] and for on-line recording of the coffee roasting process [3]. In this work a SPI-/REMPI-TOFMS system was used for studying the formation of roasting gases within individual coffee beans. For this purpose the tip of a spe-cial

microprobe sampling device was inserted in a small drilled hole in the green bean. Subse-quently the so prepared beans were roasted at 200 °C and the evolved gases from the interior of the bean were analyzed by the photo ionization mass spectrometer. In Figure 1 a difference SPI mass spectrum of the internal roast gases sampled from Arabica and Robusta varieties respec-tively is shown. The difference mass spectrum is based on three added SPI-mass spectra of each variety, averaged over the whole roasting process. The varieties can be clearly differentiated and sound discriminating compounds such as phenols, pyridin, lipids, caffeine and kahweol are de-tected. In addition to difference spectra also multivariate statistics was used to identify volatile markers for roasting degree and coffee variety.

References: [1] Anal.Chem. 71 (1999) 46, [2] Anal.Chem. 77 (2005) 2288, [3] Anal. Chem. 76 (2004) 1386

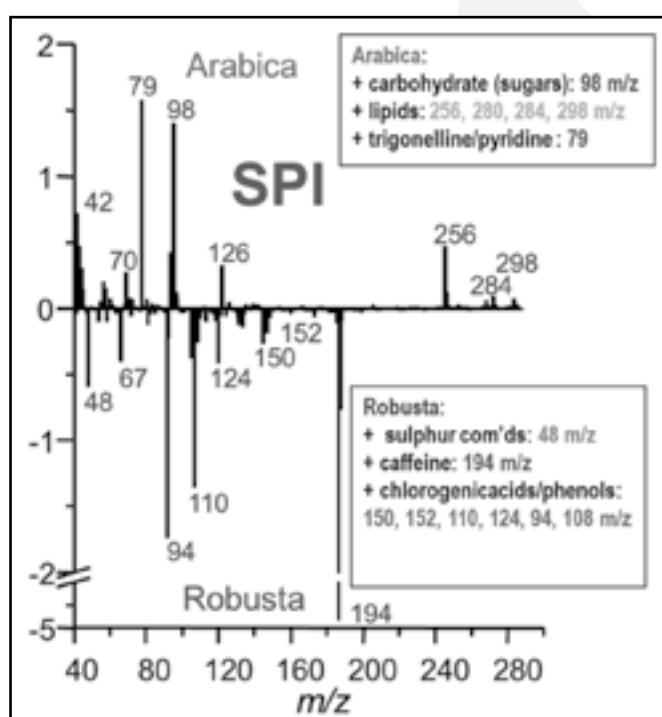


Figure 1: Difference SPI-mass spectrum of the roasting gases of the Robusta and Arabica varieties measured inside of the respective beans.

**C 5**
**ON-LINE ANALYSIS OF THE COFFEE ROASTING  
PROCESS WITH PTR-ToF-MS: CHANGES IN FLAVOR  
FORMATION FOR DIFFERENT COFFEE VARIETIES**

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Roasting is the process where volatile organic compounds (VOCs), responsible for the aroma of a cup of coffee, are generated. This strongly depends on the type of coffee being roasted, as well as the time-temperature-profile of the roasting process [1-3]. Proton-transfer-reaction time-of-flight mass-spectrometry (PTR-ToF-MS) allows examining directly and in real-time the formation of the VOCs during the roasting process itself, and in particular of the VOCs responsible for the flavor (Figure 1). In this study, a total of eight different roasting profiles, ranging from medium to dark roast degrees, were monitored for five different coffee origins: Arabica from Columbia, Antigua (Guatemala), Djimmah (Ethiopia), Yirga Cheffe (Ethiopia) and Robusta Malangsari (Indonesia). Clear differences in the VOC formation can be seen between Robusta Malangsari, Arabica from Middle America and Ethiopia; only minor differences are observable between Arabica from Columbia and Guatemala. Off-line analysis of the respective coffee brews revealed the differences in the cup, including sensory and instrumental analysis: HS SPME GC/MS for aroma analysis, content of caffeine and chlorogenic acids (HPLC), titratable acidity, content of organic acids (ion chromatography), total solids, and content of total polyphenols (Folin-Ciocalteu method).

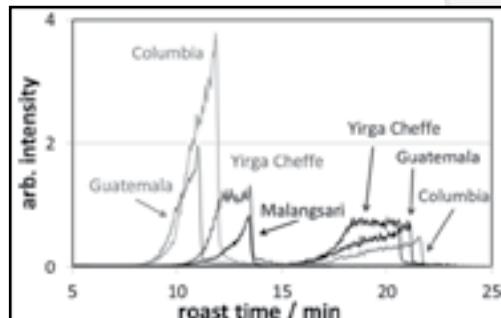


Fig. 1:  
Time-

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**C 18**
**PHYSIOLOGICAL MARKERS FOR  
QUALITY COFFEE BEVERAGE**
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Physiological tests, such as germination, 2,3,5-triphenyltetrazolium chloride (TTC), electrical conductivity (CE) and potassium leaching (LK) are used in the seed industry to assess seed quality after processing and drying. The quality of coffee beverage is also affected by the processes in the post-harvest, since they may affect the chemical composition of the flavor and aroma precursors of coffee brew. Thus, physiological and biochemical fast, accurate, economical tests and easy standardization can constitute viable alternatives for assessing the quality of the drink. However, physiological and biochemical approaches to evaluate the quality of drinking coffee are rare. In this sense, the objective of the present study was to test the potential physiological and biochemical analyses to assess the quality of coffee beverage. The research was conducted at the Federal University of Lavras/MG, Brazil. Seeds of *Coffea arabica* L., red ripe stage were used and a randomized complete block design in a 3 x 3 factorial, three types of processing (dry, wet and mechanical) and three drying methods (sun, shade and mechanical dryer). Two additional treatments were used, corresponding to samples of lower sensory quality coffee. The water content was determined and germination tests, CE, LK, TTC in the embryos, and modified TTC in the endosperms were performed in coffee beans. Coffee beans with high scores in sensory analysis, also have high germination and viability percentages and low electrical conductivity values. There were high correlations between the sensory quality results of coffee grains and physiological or biochemical tests results, with statistical significant levels less than 1% for radicle protrusion, TTC and CE. Furthermore, the evaluation by TTC in the endosperms of the coffee beans makes it possible to verify varieties of sensory quality in coffee beans.

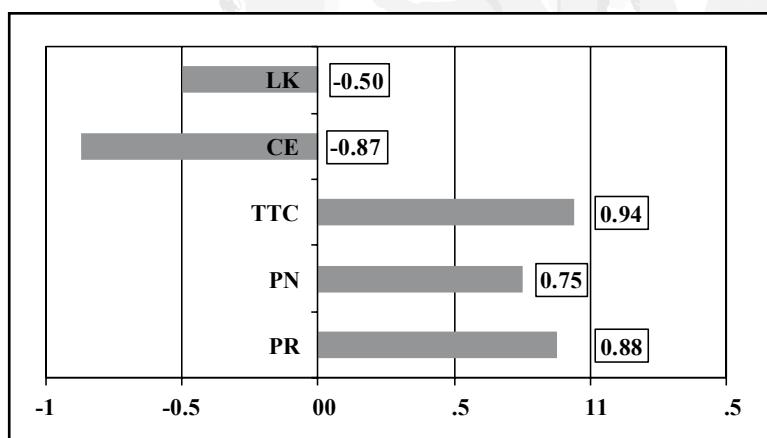


Figure 1. Correlation coefficients between the results of sensory analysis and germination (PR), normal seedlings (PN), electrical conductivity (CE), tetrazolium (TTC) and potassium leaching (LK) of *Coffea arabica* L. grains. Embrapa/UFLA, Lavras, MG, Brazil, 2012.

## C 20

### QUALITY "IN CUP" OF ESPRESSO COFFEE: DATA FROM OVER TEN YEARS OF INVESTIGATION

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This work concerns the study of quality "in cup" of "espresso" coffee. Starting from the raw material supplied by ESSSE Caffè S.p.a. of Anzola dell'Emilia (BO-Italy), the roasted coffee was assessed in terms of homogeneity of some quality parameters (colour, density,  $a_w$ ) related to roasting process. Contrarily to expected, the quality characteristics of coffee "in cup" resulted greatly various, in particular when the geographic area of brewing extraction (bar seats) changed.

A study on "espresso" coffee quality in relation to some characteristics of extraction process was carried out through different geographic zones of Italy. In several bars, visited during over ten years of investigation, the quality of espresso coffee, in terms of pH, solid content, volume, cream consistence and height, was evaluated. Data were statistically elaborated with the following aims:

- application of principal component analysis (PCA) of extraction process data and of quality parameters of espresso coffee samples in order to discriminate the quality characteristics of coffee brews in relation to the different geographic zones of Italy and to the types of used espresso extraction machine (manual, automatic, semi-automatic);

- moreover, where possible, mathematical models based on partial least square regression (PLS), multiple linear regression (MLR) and artificial neural network (ANN) were developed in order to predict some quality characteristics of "espresso" coffee brew starting from some parameters related to extraction process (water temperature and pressure, hardness of water, grams of ground coffee used, time and rate of extraction).

## C 13

### IMPACT OF CREMA QUANTITY AND APPEARANCE ON EXPECTED AND ACTUAL COFFEE PERCEPTION

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For consumers, the smooth, dense, hazelnut brown crema on top of a freshly brewed espresso is highly appreciated as part of the coffee experience. In a previous study we reported how crema influences the release kinetics of volatiles from the espresso coffee prior to consumption (1). It was found that the presence of crema enhances the release of aromas in the first 2 minutes after extraction. At longer times the crema acts as a cover that prevents aromas from escaping.

In the current study we further deepened our understanding on how crema quantity impacts aroma release from espresso coffee. Aromas were analysed above the cup as well as in mouth. Furthermore, a study was conducted aiming at understanding how crema appearance impacts the expectation and the actual perception of espresso coffee. Seven espressos were prepared using the same coffee blend. By varying the extraction parameters as well as a filtering after extraction, we obtained samples with different cremas covering a wide visual diversity but with similar aromatic profiles as determined using monadic sensory analysis. One espresso without crema was used as a reference. Results showed that for the whole cup experience including the crema, changing extraction parameters and filtration induced significant differences in above cup aromas depending on the volatility of the aromas. These differences could be confirmed in mouth. Results on appearance and expected perception demonstrated that differences in crema led to expectations modulating in-mouth perception.

Our findings show the importance of crema properties, both for the impact on aroma release as well as on the perception of the product.

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## C 14

### MILK MODIFIES COFFEE SENSORY PROPERTIES AND REVEALS UNEXPECTED NOTES

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More than half of coffee beverages worldwide are drunk in combination with milk. The in-cup result can range from a dash of milk to a latte macchiato, beverage dominated by milk. The choice of beverage depends both on culture as well as on personal preferences.

The choice of coffee to be used for the preparation of the milk based beverage is of very high importance. The general recommendation made by coffee experts and baristas is to use strong coffees in order to allow the perception of the coffee aromas in the presence of milk.

In the current study we aimed at understanding how a coffee range with a wide aromatic variety will express its aromatic notes in the presence of milk, and more specifically, how the quantity of milk impacts the result in cup. Thirty assessors were invited to four sensory sessions, each one dedicated to a specific beverage i.e. black coffee, coffee with a dash of milk, cappuccino and latte macchiato. The sensory procedure was the same for each session and consisted in sorting tasks followed by description of the groups using a common list of attributes.

The comparison of mappings obtained with different milk quantities shows that the perceptual space is modified. However, this modification is not due to a simple masking of coffee notes in presence of milk but to a real modification of the coffee sensory properties. Thus, some of the sensory dimensions of the black coffees remains, some seem to be masked (e.g. acidity) others seem to be revealed as biscuits or caramel notes.

It can be concluded that not only intensively roasted coffees should be recommended and that distinctive coffees allow the preparation of differentiated milk based beverages.

C 10

CHARACTERIZATION OF ANIMAL PREFERENCE TO ARABICA COFFEE VARIETIES AND FLAVOR PROFILE ON DOMESTICATED «LUWAK» (*Paradoxorus Hermaphroditus*)

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“Luwak” coffee was known as a very unique coffee, because the coffee was passing through inside digestion of a wild civet cat (*Paradoxorus hermaphroditus*). During in the civet cat digestion, a unique fermentation was occurred eventually, that's producing any unique flavors substances. Production of wild “Luwak” coffee was very limited quantity. To get more “Luwak” coffee, a volunteer to domestication of the civet cat had been tried. Domestication of civet cat as coffee processing was a new method. There are 3 (three) types of civet cat hutch, those are “ranch”, individual aviary, and individual cage. Individual cage method was easier to handle. Those civet cats were fencing only during harvesting season, after that's released to wild nature. Ration of a civet cat during in the hutch is 300 grams of fruits (banana, papaya, etc.) in the morning, 1 - 1,2 kg of fresh coffee cherry in the afternoon. Every week, 250 grams of fresh chicken meat is served. Fresh water always be available in the hutch. All the ration must be served in fresh condition, and the hutch must be cleaned everyday. A trial of civet cat preference on Arabica varieties had been conducted. The most preferred variety by «Luwak» is a new promising “Komposit” variety developed by ICCRI, followed by Andungsari 2K, S795 and Kartika. A «luwak» can drop 300 - 400 grams of wet parchment a day or equivalent to 100 - 150 g green coffee. Average yield every civet cat is around 0,12 Kg a day similar to 14 Kg a season. Wild Luwak coffee contained black bean, partly black beans, holed bean, whereas the domesticated luwak coffee almost no physical defects. Wild Luwak coffee has strong Fragrance, Aroma, Flavor and Aftertaste, medium Acidity, medium body, and a good balance. But, sometimes accompanied by earthy of flavour. Domesticated luwak coffee performed very strong fragrance, Aroma, Flavor and Aftertaste, medium acidity, heavy body, and very good balance. Caffeine content of luwak coffee is not significantly different with wet processing coffee.

Key words : luwak coffee, civet cat, *Paradoxorus hermaphroditus*, flavor,

**C 15**

**1H-NMR PROFILING OF GREEN AND ROASTED COFFEE EXTRACTS: CLASSIFICATION OF COLOMBIAN COFFEES**

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The design of new products is crux for the competitiveness of Colombian coffee commercialization and thereby for the sustainability of half a million of coffee producers. As important is the ability to protect genuine Colombian coffee products from being adulterated with products of other origins. To achieve those aims several methods are currently being used, ranging from cupping to Near Infrared (NIR) spectroscopy.

Here we present results obtained using Nuclear Magnetic Resonance (NMR) to profile and classify Colombian coffees. The method, referred to as  $^1\text{H}$ -NMR profiling, has already been successfully applied to the classification of green tea extracts, and to the untargeted fraud detection in the production of fruit juices, to mention only a few.

Samples were prepared readily by extraction in aqueous buffer or in methanol at room temperature. After centrifugation, a small amount of the corresponding deuterated solvent was added to the supernatant for the lock. Proton spectra were acquired and processed in a fully automatic manner with a 400 MHz spectrometer using selective solvent suppression schemes. After Fourier transform, apodization and baseline correction, the resulting spectrum, a 128k points complex vector, was binned and stored into a 1024 real points vector prior to analysis.

At this point, two approaches were evaluated. For the first one, a standard principle component analysis (PCA) was performed and the score plots were used for classification. For the second one, the spectra were used to construct trees. These latter were then compared to build a distance matrix used for hierarchical clustering. In this case dendograms were used to visualize the outcome.

Both approaches allowed us to discriminate different species or presentation of coffee (arabica, robusta and decaffeinated), and to quantify mixtures thereof. Classification of samples according to their origin was also successfully achieved. Coffees from 5 different regions of Colombia were correctly classified.

Thus,  $^1\text{H}$ -NMR spectra contain valuable information for authenticity assessment of samples. The same data set could be further used for the untargeted detection of additional fraud or adulteration of samples.. The analysis works under full automation with a throughput of 15 minutes per sample and implies only limited costs due to the usage of non-deuterated solvents for the extraction.

**C 16**

**FREE AMINO ACIDS DETERMINATION  
IN GREEN COFFEE BEANS BY GC-MS.**

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Amino acids in green coffee are of extreme importance as they act as precursors for aroma formation during the roasting process. Some chemical classes of essential contributors to the roasted coffee aroma, such as pyrazines and pyridines, are only slightly represented in green coffee, while others are not present in the raw material as thiophenes, oxazoles and thiazols, being mainly formed through the Maillard browning by thermal reactions between amino acids and reducing sugars. Therefore, to better understand how the raw material can influence the final quality of the roasted coffee with respect to the aroma formation, the determination of the free amino acidic content in green coffee is essential. Moreover, as far as amino acidic profile is concerned, data on literature are scarce and often contrasting. This largely stimulated the present investigation aimed at characterizing the free amino acidic profile of several coffee samples from different species (*C. arabica*, *C. canephora* and *C. liberica*) and geographical origins.

In order to be determined in a complex matrix such as green coffee, the free amino acids were first extracted with hot water, purified by solid phase extraction, derivatized and then analyzed by GC-MS. The derivatization step, which consists in the alkylation of amino groups and the simultaneously esterification of carboxylic groups of amino acids, is crucial and it is required to turn amino acids into more volatile components that are consequently detectable by a gas-chromatographic technique. Using this procedure it was possible to detect more than 20 amino acids simultaneously in a single run in full scan mode.

Generally, Arabica and Robusta show similar free amino acid profile. For both species main amino acids are glutamic acid, aspartic acid and asparagine. Liberica shows a different profile with alanine particularly abundant. The content of γ-aminobutyric acid (GABA) in Robusta and Liberica is remarkably higher than that in Arabica. In the present work differences in free amino acids concentrations among different species and geographical origins will be discussed.

**C 7**

**OLEOSOMES IN DEFECTIVE ARABICA BEANS**

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Coffee defects can be identified by observing the colour of silverskin and/or that of the bean endosperm. Black beans result from dead beans or beans that fall naturally on the ground; sour beans are often associated with 'over-fermentation' during wet processing. According to the Brazilian Official Classification System, black beans and immature beans are between the worst types of defects, known to affect beverage quality. Defective

beans, however, can represent a source of valuable chemicals or raw materials and then the cell content of these beans is an interesting topic to be studied. Coffee oil extraction from defective beans has been suggested as possible process to obtain chemicals and energy through biodiesel conversion. The objective of this work was to characterize the oil bodies of defective beans and to carry out a comparison with normal beans both dry and wet processed.

Transversal sections of 1-2 mm of brazilian black, sour, immature and normal beans were pre-fixed in glutaraldehyde in phosphate buffer. Portions of these sections, that represent only the external endosperm, are subsequently fixed in the same solution. After a post-fixation in osmium tetroxide, samples were dehydrated with increasing acetone series and included in Spurr's resin (Spurr, 1969). Then, they were cut to obtain ultrathin sections, treated with standard double contrasting stain and examined by TEM. The oil fraction was isolated by a standard Soxhlet extractor.

Other seeds, fixed in formaldehyde solution for almost 3 weeks, were cut with a cryostate to obtain frozen section, stained with some histochemical techniques and examined by a standard optical microscope.

The morphological aspect of immature seeds was similar to normal seeds, with small oil bodies at the cell periphery. Black beans were different from the others, with their very hard cell-walls and the presence of mold. Oil bodies were inside the more internal endosperm cells, sometimes completely fused. In sour beans, characterized by a higher quantity of oils, there are bigger oil drops and an unknown protein matrix, probably a consequence of the fermentation process.

## C 9

### IDENTIFICATION OF PHENOLIC AND CAROTENOID COMPOUNDS IN COFFEE (*COFFEA ARABICA*) PULP, PEEL AND MUCILAGE BY HPLC ELECTROSPRAY IONIZATION MASS SPECTROMETRY

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Coffee pulp, peel and mucilage are by-products in the coffee industry. These residues could be used for animal feeding, composting, as fuel and in the food industry. Like coffee seeds, these tissues contain large amounts of polyphenolic and other yet-unknown compounds. Identifying and knowing the exact amount of these compounds would foster their use for other purposes. In the present study polyphenols and carotenoids were identified separately in the coffee fruit (pulp and peel) of five coffee varieties planted in Tres Ríos, Cartago, Costa Rica, and in the mucilage obtained after commercially depulping coffee from a mixture of varieties. Peel and pulp of each fruit were manually separated and approximately 0.5 g of lyophilized tissue was used for polyphenol and 1 g for carotenoid extraction. Compounds were characterized by high-performance liquid chromatography/electrospray ionization mass spectrometry. Quantification of individual phenolic compounds was carried out by external calibration. Most of the polyphenols detected were chlorogenic acids (CQA), such as caffeoylquinic acid isomers, feruloylquinic acids and p-coumaroylquinic acids. Differences in the concentration of each compound were found between coffee varieties and tissue (pulp and peel). Concentration of the isomer 5-CQA was higher in the pulp than in the peel while concentrations of other caffeoylquinic acids were higher in the peel. Other phenolic compounds, such as epicatechin, vanillic acid and proanthocyanidin B, were found in the pulp and the peel. Carotenoid compounds, like violaxanthin, neoxanthin, lutein, α-carotene and β-carotene, were detected. Lutein showed highest contents, with differences among varieties. Remarkably, 5-O-dimethoxycinnamoylquinic acid was found only in the mucilage.

## C 2

### BETA-SITOSTEROL Ð A PARAMETER FOR STUDYING THE COFFEE PROPORTION IN COFFEE DRINKS

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In the last years coffee drinks have become more and more popular as a quick and uncomplicated solution for an occasional consumption of coffee. They are available in the refrigerated sections in most supermarkets. They belong to the milk-based drinks and consist of at least 70% milk and, at most, 30% of other ingredients such as coffee, sugar, rheological additives, cocoa, flavourings, and sometimes caffeine [1]. According to the declaration on coffee drinks, the coffee proportion may be a solid or liquid coffee extract, or a coffee brew, and range between 0.8 to 19% of the beverage.

The principal aim was to assess the percentage of the coffee proportion. Due to its sufficiently low natural limits of variation and low changes during the roasting process the sterol fraction was chosen. In this fraction,  $\beta$ -sitosterol is the main component with an approximate and nearly constant ratio of 50%. Therefore, it presents itself as the best component for quantification [2].

At first, a method was established for model drinks consisting of milk and espresso. The determination of the  $\beta$ -sitosterol content depends on the percentage of milk. The attempts to analyse the  $\beta$ -sitosterol content in coffee drinks will be presented.

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## C 6

### POTENTIAL OF DIFUSE REFLECTANCE FOURIER TRANSFORM INFRARED SPECTROSCOPY (DRIFTS) FOR DETECTION OF ADULTERATION IN ROASTED COFFEES

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Ground roasted coffee is quite vulnerable to adulteration because it presents physical characteristics (particle size, texture and color) that are easily reproduced by roasting and grinding a variety of biological materials. Therefore, this food product has been the target of fraudulent admixtures with a diversity of cheaper materials, such as twigs, coffee husks, spent coffee grounds, and roasted grains such as barley, soybean, corn and others (Oliveira et al., 2009). Given that spectroscopic methods have been successfully applied for quality analysis of food products, including roasted coffee (Franca and Oliveira, 2011), the objective of this work was to evaluate the potential of Diffuse Reflectance Fourier Transform Infrared spectroscopy (DRIFTS) for simultaneous discrimination between roasted coffee and the following adulterants: spent coffee grounds, coffee husks, roasted corn and roasted barley. Coffee beans and adulterants were submitted to batch roasting in an oven at temperatures ranging from 200 to 270°C. Roasting conditions were established based on color measurements ( $L^*a^*b^*$  color parameters) in comparison to commercially available roasted coffee samples. Multivariate statistical analysis was performed in order to verify the possibility of discrimination between coffee and adulterants. Principal Components Analysis provided separation of the samples into four groups: coffee, coffee husks, spent coffee grounds and corn/barley. Classification models were developed based on Linear Discriminant Analysis and recognition and prediction abilities of these models were 100%, with the samples

being separated into five groups: coffee, spent coffee grounds, coffee husks, corn and barley. Such results confirm that DRIFTS presents potential for the development of an analytical methodology for detection of adulteration in roasted and ground coffee.

**Acknowledgements:**

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C 8

**PURSUING GREEN COFFEE GEOGRAPHIC ORIGIN  
DISCRIMINATION THROUGH RELATIONS BETWEEN ISOTOPES  
AND ENVIRONMENTAL FACTORS (ISOGEOCOFFEE PROJECT)**

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In the present work, several spectroscopic techniques were applied for the differentiation of different types of coffee and of their geographical origin. In a first approach, a study on the application of Raman spectroscopy to the differentiation of coffee type (*Arabica* versus *Robusta*) was developed based on the determination of kahweol content. Isotope Ratio Mass Spectrometry (IRMS) was then applied for the determination of the isotopic composition of carbon (C), nitrogen (N) and oxygen (O) of the green coffee bean, allowing coffee differentiation at continental level. Subsequently, IRMS was combined with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to determine the isotopic composition of strontium (Sr) in the coffee bean. The results obtained demonstrated that the isotope ratios of Sr and O of the coffee bean are a promising tool for its traceability, as these elements reflect the local geology and hydrology. In order to expand the understanding of how environmental factors determine the isotopic composition of the different elements on the green coffee bean, further research was developed focusing the region of Hawaii. The results allowed for the differentiation of the different coffee-producing regions of Hawaii. In addition, IRMS was also applied to measure the oxygen isotopic composition of the caffeine molecule ( $\delta^{18}\text{O}_{\text{caff}}$ ), previously extracted from the green coffee bean. O isotopes of caffeine molecule originate from the metabolic water of plant tissues, and accordingly results showed that this organic specific compound may be relevant for studies on the coffee plant ecophysiology.

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C 19

## DETECTION OF CORN AND BARLEY AS ADULTERANTS IN ROASTED COFFEE USING REAL-TIME PCR.

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Coffee is one of the main commodities in Brazil and, as such, it has been a target for fraudulent admixtures with a diversity of cheaper materials, such as twigs, spent coffee, roasted barley and corn. Many techniques have been developed in order to establish suitable parameters and markers for adulteration of ground roasted coffee and instant coffee. However, these methods usually present low sensitivity and specificity. Although the recombinant DNA technology has shown to be a promising tool to determine the authenticity of processed foods, it has not been used to detect coffee adulteration. The objective of this study was to use a real-time Polymerase Chain Reaction (PCR) based method for detection of two among the main adulterants in coffee: corn and barley. For this purpose, ground coffee blends containing 80% of *C. arabica* and 20% of *C. canephora* were intentionally adultered with corn and barley, in the proportions of 0.05; 0.5; 5 and 50mg per g of coffee and thoroughly mixed. In addition to these samples, roasted corn, barley and plain coffee were separately assayed for standard curves preparation. DNA extractions were performed using a modified version of DNeasy kit protocol and CTAB buffer. The DNA concentrations were determined by spectrophotometry (Shimadzu UV-1800 Japan) at 260 nm. Primers for corn (ZEINA2) and for barley (CEVADA3) were designed through the on line program GeneFisher2. The reaction was conducted using qPCR (SDS ABI Prism 7000 - Applied Biosystems USA), with SYBR Green I system (Applied Biosystems, UK), in quadruplicate. The method was sensitive and specific to detect down to 0.02 ng of corn DNA and 0.005ng of barley DNA per g of roasted coffee, which converted to mass could be estimated in approximately 307 µg corn/g coffee and 45 µg barley/g coffee. The methodology based on real- time PCR appears to be more efficient to detect small amounts of adulterants, compared to other existing and routinely used methodologies, showing to be a promising tool for the detection of corn and barley in commercial coffees.

Financial support: CNPq, FAPERJ

## C 4

UNTARGETED METABOLOMICS:  
A POWERFUL TOOL IN COFFEE RESEARCH

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Comprehensive metabolomics profiling techniques are nowadays frequently applied in plant biology and food research in order to get a detailed view of the effects, for instance, of genetic variation, biotic and abiotic stress, growth conditions, food processing, etc. Especially untargeted approaches, in which all metabolites detected in the samples, both known and yet unknown, are taken into consideration, have provided novel insights into key metabolites and biochemical pathways related to economically important traits of (crop) plants and their products. In this presentation, examples of results applying untargeted LCMS- and GCMS-based metabolomics in coffee quality research will be provided.

Firstly, to get more insight into the effects of post-harvest processing on the metabolite composition of green coffee, ripe *C. arabica* (var. Topacio) berries were both dry and wet processed and dried at different conditions at an experimental plantation in Brazil. The beans were subsequently comprehensively profiled using various untargeted metabolomics platforms. Substantial, processing method-dependent effects on the metabolite composition were identified upon drying fresh seeds to dry coffee beans, including differences in sugars and amino acids known to be involved in roasting-induced Maillard reactions. In addition, due to the untargeted approach, new metabolite markers for specific processing conditions could be proposed. Secondly, we are using untargeted metabolomics approaches in research aimed at identifying key compounds for coffee cup quality. By correlating untargeted headspace-GCMS profiles to coffee sensory data, we discovered ethylformate as a new marker compound related to the fermented off-note occasionally perceived in coffees. Finally, in order to establish possible relations between the metabolite composition of green coffee with that of its roasted final product, from 65 different Arabica and Robusta coffee lots we analyzed green, half-roasted and fully-roasted beans, as well as their freeze-dried hot-water extracts, using different untargeted metabolomics platforms. Through regression analyses we were able to identify significant metabolite correlations between green and roasted coffee beans, as well as with odour compounds in the extracts.

These examples show that metabolomics, especially the untargeted approaches which provide the most comprehensive view of differences between metabolomes, is a powerful technique in coffee research that can be applied at all steps from fruit development up to its final product, i.e. a cup of coffee with optimal sensory characteristics.

## C 12

EFFICIENT DIGESTION OF THE COFFEE BEAN CELL WALL USING  
FOOD-PROCESSING CELLULASE AND MICROORGANISMS**KASAI, Naoya and SAKAMOTO, Tatsuji***Graduate School of Life and Environmental Sciences, Osaka Prefecture University, Osaka JAPAN*

Although huge amounts of coffee beans are processed annually and their residues are a valuable resource, little is known about the enzymatic digestion of coffee beans. Whether coffee beans are indigestible materials is unknown. Our study aims to enzymatically digest coffee beans and to analyze some indigestible fibers or residues from plants after food processing. Our results reconfirm the presence of few indigestible fibers.

Plants are principally made of carbohydrates, proteins, and lignin; therefore, effective digestion is possible with some enzymes and chemical or physiological treatments. However, fibers, cell walls, and tissue contents of coffee beans have a unique composition or complex, and they are sometimes strongly resistant to general enzymes.

Our study aims to achieve efficient enzymatic digestion of coffee beans, and various trials and screenings of food-processing enzymes have been conducted. In our results, a food-processing cellulase from *Trichoderma reesei* was found to be an efficient enzyme for digesting the coffee bean cell wall, and the cell wall was drastically collapsed and digested. High-molecular-weight galactan, oligomannose, arabinose, and glucose were found in the digested supernatant. Rhamnose and galacturonic acid, which are the components of rhamnogalacturonan, from pectin were found in the small digested particles of the collapsed cell wall.

In addition to this efficient enzymatic digestion of coffee bean cell walls, we would like to present the characteristics of the enzyme and digestion components and also reveal the mechanism, key enzymes, and strategies for efficient enzymatic digestion. We also would like to present our recent investigations and trials on digestion of the key components of arabinogalactan or its protein and of coffee bean hulls.

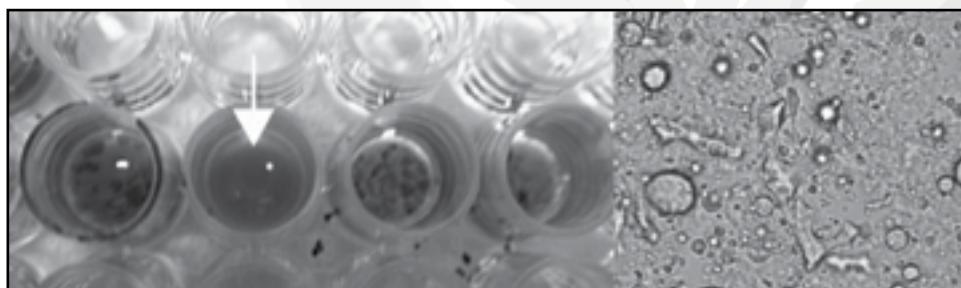


Figure: a selected food processing enzyme was efficient to digest coffee bean cell-wall (Left). The photo of microscopy of the digested and collapsed coffee bean cell-wall (Right).

**C 11**
**IDENTIFICATION OF THE FUNGAL MICROFLORA OF COFFEE BEANS FROM DIFFERENT ORIGINS AND EVALUATION OF DIFFERENT DECONTAMINATION CONCEPTS.**

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The aim of this work was to identify the fungal microbiota naturally occurring on commercial green coffee beans, belonging to both *Coffea Arabica* and *Coffea robusta* varieties, and to evaluate different approaches for the disinfection of the bean surface. In general, the coffee beans had a moisture level of 10-13% upon arrival and, depending on the sources; they had either an intact husk or were husk-free.

Endogenous fungi were isolated using RBA, PDA and MEA agar and identified by DNA sequencing and morphological analysis. The fungal isolates belonged to *Aspergillus* and *Penicillium* spp.

Different chemical, physical and biological methods were employed to control and/or inhibit the fungal growth on the beans. Chemical methods involved soaking of the beans in food grade chemical disinfectants, i.e. quaternary ammonium compounds, bisulphite-based liquids, H<sub>2</sub>O<sub>2</sub>, NaOCl, a NaCl segregated ion solution, and organic acids. Physical decontamination methods included; UV, microwave, heat, pH, and high pressure treatments. Decontamination by selected lactic acid bacteria (LAB) fermentation of the coffee beans and by incorporation of a crude mixture of LAB-derived anti-fungal compounds was also investigated. The effectiveness of the decontamination approaches were evaluated in terms of; (i) percentage of coffee beans showing contamination during prolonged incubation and, (ii) viability of the beans after the decontamination treatment.

In general, the use of chemical methods and fermentation were shown to be the most successful approaches. The duration of the fermentation and soaking in the decontaminant solutions was a critical factor influencing the efficiency of the treatments. When soaking times shorter than 12 h were applied, visible fungal growth was observed protruding from the lower fold of the beans after 48 h of incubation. Prolonged soaking/fermentation prevented this growth; however it also resulted also resulted in dramatic loss of viability. On the contrary, soaking in LAB-derived antifungal compounds allowed complete inhibition of fungal growth but didn't affect the viability of the coffee beans to the same extent.

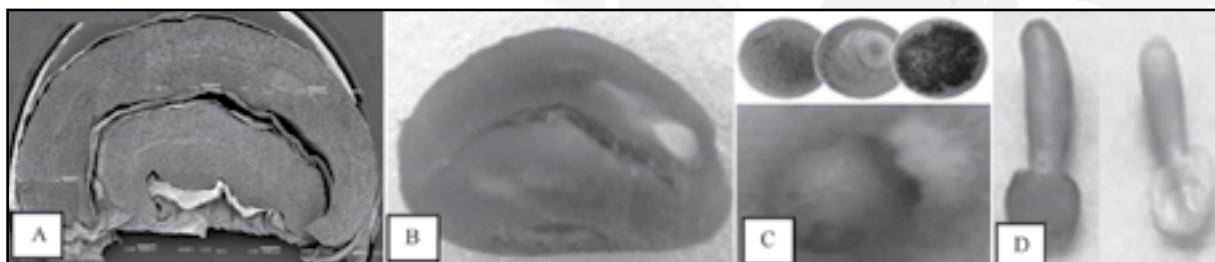


Fig 1. A) SEM picture of the longitudinal cut of *C. robusta* green coffee bean; B) *C. robusta* green coffee bean; C) Green coffee beans with fungal contamination; D) Viable (red) and dead coffee bean embryos (TTC).

## C 17

## DYNAMICS AND BIODIVERSITY OF MICROORGANISMS (FUNGI, BACTERIA, YEAST) BY PCR-DGGE, LINKED TO ORIGIN AND POST HARVEST TREATMENTS ON COFFEE BEANS.

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The dynamics and biodiversity of microbial populations (fungi, yeast and bacteria) on coffee beans were monitored using PCR-DGGE (Polymerase Chain Reaction - Denaturing Gradient Gel Electrophoresis), a rapid molecular technique that provides a snapshot of the global microflora associated with food products. The different steps of the approach (total DNA extraction and PCR amplifications (16S, 26S and 28S rDNA from bacteria, yeast and fungi respectively) were optimized. Detection limits were estimated on several fungi, yeast, and bacterial species. Additionally, repeatability of the methodology was tested.

This work aimed at isolating and identifying the microbiota associated to different methods of coffee processing. The microbial diversity associated with both wet (wash, semi-wash, natural) and dry processing was evaluated on samples of *Coffea arabica* L. and *Coffea canephora*, which were collected during different post harvest processing stages in Mexico, Venezuela and Cameroon.

Our objective is to understand the dynamics of microbial populations linked to post harvest treatments, origins of coffee production, and levels of OTA production through statistical analyses of DGGE fingerprints.

## P 3

## STUDY OF GREEN COFFEE PROCESSING AND BREWING VARIABILITY ACROSS SPECIES, ORIGINS, GRADES AND TIME.

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Like most agricultural products, green coffee varies due to natural conditions. This natural variability leads to variations in processing and brewing performance. The present work aims to quantify these natural variations across a broad range of bean origins and grades over a period of four months. Processing and brewing performance was assessed in regards to organic roast loss upon roasting, total solids extractable at atmospheric pressure and foaming properties of the extracts. It was observed that differences across green coffee origins were of the order of 30%, and that the variations within green coffee origins ranged from 3% to 20%. These results indicate a significant impact of raw material differences and seasonal variability on industrial performance, and should therefore be taken into account when aiming to achieve consistent product quality.

P 2

## THE EFFECT OF EFFECTIVE MICROORGANISM (EM) FOR CLEANING EFFLUENT FROM COFFEE WASHING MILLS IN ETHIOPIA

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Effective and Beneficial Microorganisms (EM) are a mixed culture of, fermentative, soil-based, beneficial microorganisms which can be applied to many environments to break down organic matter. The objective of the experiment was to evaluate the efficiency of Effective Microorganisms (EM) in managing coffee processing effluent generated from wet mill stations. The experiment was conducted in constructed coffee effluent holding concrete pits and plastic tank in three replications under controlled green house condition at Jimma Research Center. The treatment of EM decreased COD, BOD, TDS, DO and pH but did not affect the temperature of waste water. The effect of EM on the pH showed that there was a significant difference between the different concrete ponds in application of EM. However, it was observed that tank treated with EM had neutral pH (7.37). The result also showed that with no application of EM the pH tended to rise to 8.37 towards the end of experiment. The COD, BOD and TDS increased 11 days after EM treatment. Fifteen days after EM treatment the BOD and VOD value of coffee waste effluent was reduced by 80 percent and 87 percent respectively. In addition, the ammonia, Orthophosphate, Nitrate, Nitrite and Total phosphate content, was also decreased by 98, 71, 49, 46 and 67 percent respectively, due to the microbial breakdown of organic matter. Physico-chemical characteristics of coffee effluent of the two treatments were significantly different before and after application of EM. The levels of ammonia, BOD, COD, orthophosphate, Nitrate and Nitrite were low and the pH values were within acceptable range. Without application of EM in final effluent allows little or no larva re-growth compared with EM treated coffee effluent pond. This result suggests that EM can control the coffee effluent and had significantly reduced coffee effluent waste odour. These reductions could be attributed to the microbial utilization of these nutrients, thereby making the water suitable for recycling for agricultural purposes. EM has proved to be an effective biological agent in waste treatment system.

Key words: coffee pulp effluent, Effective microorganisms, Bokashi,

## ENHANCEMENT ARABICA COFFEE FLAVOR BY INVOLVING BIOLOGICAL AGENTS DURING FERMENTATION PROCESS

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A rare, distinct and unique coffee in the world is 'Kopi Luwak' which is produced by involving a native animal behavior of "Luwak" (*Paradoxorus hermaproditus*), a civet cat. "Luwak" is native animal in South East Asia region particularly in Sumatra and Java islands. An experiment of fermentation Arabica coffee involving biological agent such as luwak animal had been done at Andungsari Experiment Station of ICRRI during harvesting period of 2010. Material used in this fermentation trial was fresh depulped Arabica coffee beans. The depulped beans were fermented by several different treatments involving fermentation methods, biological agents and duration of fermentation. The fermentation methods consisted of underwater fermentation (A1) and dry fermentation (A2). The biological agent treatments used in this trial were no involvement of biological agent (B0), fresh "Kopi Luwak" (B1), yeast of a traditional fermented cassava cake (*Sacharomyces sp.*) (B2), fungus of "Tempe" (*Rizopus sp.*) (B3) and bacteria of yogurt (*Lactobacillus sp.*) (B4). Duration of fermentation treatments were 12 – 14 hours (C1) and 36 – 38 hours (C2). The fermented coffee parchments were washed and followed by fully sundried until 12 % of moisture content. After deparchment the green coffee samples were roasted at medium level (Agtron Scale at 65#) for cupping test involving 5 specialists at ICRRI laboratory by using SCAA's protocol. The results showed as follows (1) dry fermentation performed better flavors than that of underwater fermentation, (2) treatments with biological agent during fermentation indicated better flavor than that of no biological agent involvement, (3) bacteria of yogurt (*Lactobacillus Sp.*) provided the best effect on flavor enhancement than that of other microbe inoculums, (4) fermentation duration of 12 hours indicated better flavor than that of 36 hours, (5) 'Kopi Lusaka' performed the best flavor than that of all fermentation treatments. It was assumed that higher fermentation temperature inside "Luwak" ingestion (35 - 37 °C) than that of common fermentation process (21 – 23 °C) as well as a complexity relationship between other unknown factors provided a significant effect in generating an excellent flavor on Arabica coffee.

**Keywords:** *Coffea arabica*, kopi luwak, fermentation, specialty coffee, flavors, *Paradoxorus hermaproditus*. The current study shows that the acid value and seed viability are potential green coffee storage markers and could be proposed as quality control markers for green coffee under storage. These markers are correlated to defective sensory attributes detected by a trained panel.

## IDENTIFICATION OF BIOCHEMICAL AND PHYSIOLOGICAL MARKERS RELATED TO GREEN COFFEE UNDER STORAGE

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Coffee flavour is associated with the chemical composition and physical characteristics of green coffee. Different factors like temperature and air humidity can modify the coffee cup quality over time and also its biochemical composition. It is already demonstrated that the bean life and the cup quality can be preserved by storing the beans in appropriate conditions.

The aim of the current work is to identify chemical, physical and physiological modifications in green coffee during storage under different conditions. These modifications are compared to the sensory quality trying to identify potential markers for the coffee shelf life.

The experiment is organized with one single batch of Arabica coffee originated from Ecuador and produced with a fully washed process. The batch is divided into 11 samples stored at different conditions which are a combination of 3 parameters: temperature, humidity, and oxygen. Portions of all samples are withdrawn at 3, 6 and 9 months for chemical, physical and sensory analyses. To simulate warehouse storage, one sample is kept at ambient temperature.

The green coffee samples stored at high temperature and humidity undergone rapid and important chemical and sensory changes. In these conditions, the coffee beans are no longer viable according to TTC viability test and the lipid fraction contains high amounts of free fatty acids. High concentrations of acetic acid are detected under confined storage conditions and leading likely to the reduction of the germination capacity of the bean. Furthermore, there is a decrease over time in chlorogenic acids and total sugars contents but the decrease is not correlated neither to a specific storage condition nor to the viability of the beans.

The current study shows that the acid value and seed viability are potential green coffee storage markers and could be proposed as quality control markers for green coffee under storage. These markers are correlated to defective sensory attributes detected by a trained panel.

**P 5**

**DRYING RATE AND QUALITY OF NATURAL COFFEE**

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\*Federal University of Lavras, MG, BR, \*\* IAC Agronomic Institute of Campinas; \*\*\*State University of São Paulo, SP, BR.

The processing of coffee through the dry method is the most used in Brazil. Due to a lack of care and inadequate management of natural coffee during post-harvest, natural coffee is usually associated with poorer quality when compared to coffees processed by wet method. However, correct management of the harvest, processing and drying of the fruits allows for the production of natural specialty coffees. The effect of drying temperature on the quality of coffee has been well studied. Recent research shows that natural coffee loses quality when dried at temperatures above 40° C (OLIVEIRA, 2010; TAVEIRA, 2009). However, few studies describe the effects of interactions between temperature and relative humidity of the air used in drying, and the effects of the drying rate on the quality of natural coffees. This work was carried out with the objective to study the effects of temperature and drying rate on the quality of natural coffee. The ripe fruits of coffee (*Coffea arabica* L. cv. Mundo Novo) were harvested and selected manually. Then, the selected ripe berries were sun dried in a suspended bed, until they reach a moisture content of approximately 0.5 kg.kg<sup>-1</sup> (db) (30 - 35% wb) and then dried with heated air. Three dry bulb temperatures were used (35, 40 and 45 °C) and three drying rates for each dry bulb temperature were obtained by the combination between the dry bulb temperatures and dew point temperatures (2.6, 10.8 and 16.2 °C). The immediate and latent effects of treatments on the quality of coffee were studied through analysis of total titratable acidity, total sugars, reducing and non-reducing sugars, electrical conductivity, leaching of potassium, free fatty acid profile and sensory analysis. The observed data showed that: the temperature of 35 °C is recommended for the production of natural specialty coffees; the temperature of 45 °C is not recommended for the production of specialty natural coffees; the drying rate affects the quality of natural coffee; raising the rate of drying at temperatures of 35 °C and 40 °C has a negative effect on the quality of natural coffee; the quality of natural coffee is influenced mainly by the thermal damage in dry air heated to 45 °C; natural coffees submitted to a drying air temperature of 35 °C and low drying rates showed better quality in comparison with coffee sun dried on a suspended bed.

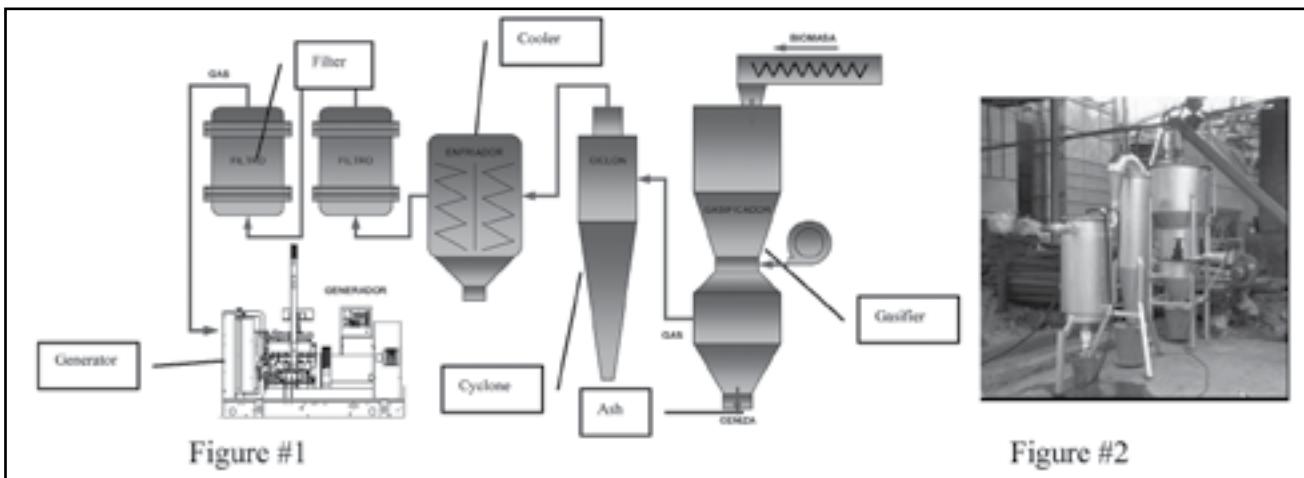
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**P 1**
**GASIFICATION OF BY-PRODUCTS FROM THE COFFEE PROCESSING FOR POWER GENERATION**

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 This paper discusses the development of a pilot plant for the biomass gasification of by-products from the coffee processing (dry pulp and husk), to use it as fuel for a 60 kw Generac® electric generator.  
 The pilot gasifier construction involved designing and consulting different aspects at the coffee mill “*Beneficio CopeDota R. L.*”, located in Santa María de Dota, province of San José, Costa Rica. Parts and materials from the coffee mill were used to reduce costs and facilitate the construction.



This pilot plant was made with a down draft gasifier fed with biomass at the top through an helical elevator, centrifugal forced-ventilation fan for insufflation of combustion air, electromechanical vibrator to move the inner material, cyclone, gas cooler and water-retention filters, and coal tar, as shown in figures # 1 and # 2.

The assessments reported a biomass consumption of 71.43 kg/hr, with a total gas production of 183.6 m<sup>3</sup>/hr, calorific value of 1402 kcal/m<sup>3</sup> using husk as biomass, and achieving 87.9 percent gasification efficiency. The chemical composition of the gas obtained is mainly 18.1 percent carbon monoxide, 2.85 percent methane, 9.10 percent hydrogen, and 11.6 percent carbon dioxide and other gases.

The energy generated by this system will be used as power supply for a small coffee processing plant, in the wet stage, with a capacity of 7500 kg/hr coffee cherries, which includes: 1 pump for coffee cherries, 2 pulp removers, 1 sieve for coffee without pulp, 1 vertical mucilage remover, 1 pump for best-quality parchment coffee, 1 pump for lower qualities, 1 helical transport and 1 helical elevator.

Currently, the gasification pilot plant is in the coupling stage to the electric generator.





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## ORAL SESSIONS

**Wednesday, November 13, 2012**



**B 1**

**FROM GENOMICS TO VARIETAL IMPROVEMENT IN COFFEE**

**LASHERMES, Philippe**

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Coffee species belong to the Rubiaceae family, one of the largest tropical angiosperm families. More than one hundred coffee species have been identified and new taxa are still being discovered. All coffee species are diploid ( $2n=2x=22$ ) and generally self-incompatible, except for *C. arabica* which is tetraploid ( $2n=4x=44$ ) and self-fertile. Although considerable diversity exists in diploid *Coffea* species, its use in conventional *C. arabica* breeding programs has been very limited due to genetic barriers. Similarly, the large genetic diversity observed in *C. canephora* is still largely unexploited. The ability to capture and efficiently use the abundant genetic resources in coffee breeding programs is therefore considered as essential for sustainable coffee production in the context of climate change.

The advent of next-generation sequencing (NGS) technologies has revolutionized approaches to biology. High throughput DNA sequencing, coupled with improved bioinformatics and statistical analyses is bringing about major advances in the field of molecular plant breeding.

As part of an international initiative, an improved high-quality draft genome sequence of a genotype of *C. canephora* has recently been completed. This reference genome sequence provides access to the relatively complete coffee gene catalog, the regulatory elements that control their function and a framework for understanding genomic variation. This sequence enables powerful integrative approaches for the identification of key genes for important traits in coffee, driving genomics-based approaches to efficiently exploiting the natural genetic diversity and offers the potential to completely renew strategies for both *C. arabica* and *C. canephora* breeding. Structural and functional genomics methodologies provide the platform for studying the genetic component of many traits as well as the associated variation in the germplasm.

Main advances in our understanding of the coffee genome and its biology as well as promising applications of genome sequencing for coffee improvement will be presented.

**B 2**

**DIFFERENTIAL EXPRESSION OF WRKY TRANSCRIPTIONAL FACTORS IN ENDOSPERM TISSUES DURING STRESS AND ONTOGENY OF FRUITS OF COFFEA CANPEHORA WITH RESPECT TO CAFFEINE BIOSYNTHESIS**

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Caffeine is the major purine alkaloid present in the leaves and beans of coffee and has been proposed to play a role in defense (chemical defense theory) against pathogen/parasite attack and herbivores. Caffeine biosynthesis, which involves the sequential methylation of xanthosine precursor, is catalyzed by enzymes of the SAM-dependant N methyltransferase (NMT) multigene family. Regulation of caffeine biosynthesis however remains to be illustrated although preliminary data suggest that the age of plant organs as well as light may play an important role. The promoter of theobromine synthase-like gene of *Coffea canephora* carry several motifs for light and WRKY family of transcription factor and this forms the basis of the present analysis. WRKY is a large group of zinc finger transcription factors (72 members in *Arabidopsis thaliana* and 102 members in *Oryza sativa*) implicated in stress and developmental responses. Many of these factors are known to work downstream of salicylic acid signaling pathway. Treatment of leaves of *Coffea canephora* with salicylic acid and methyl jasmonate augmented the biosynthesis of methyxanthines (theobromine and caffeine) correlating with the increased expression of the NMT genes. Data-mining of the *Coffea canephora* unigene database at the solanaceae genome network initiative identified 31 WRKY-like genes out of which 19 unigenes had the sequence information of the 60 amino acid DNA-binding WRKY domain. These unigenes belonged to all major classes of WRKY genes studied in *A. thaliana* as indicated by the phylogenetic analysis. Under abiotic elicitor stress viz., methyl jasmonate and Salicylic acid, differential expression of these transcription factors was investigated in leaves and also during ontogeny of coffee endosperm. We have identified clusters of WRKY transcriptional factor genes co-expressing with the NMT genes. The expression pattern of TFs in concomitant with caffeine content is hypothesized. Further studies including yeast-one-hybrid assays are underway to validate the role of WRKY genes in stress induced and developmentally regulated expression of NMT.

## B 4

## ANCESTRAL SYNTENY SHARED BETWEEN DISTANTLY-RELATED PLANT SPECIES FROM THE ASTERID AND ROSID CLADES.

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*Coffea* genus belongs to the Rubiaceae family, the fourth largest family of angiosperms. To date, this genus encompasses 124 perennial species, all native of Africa, Madagascar, the Mascarene and Comoros Islands, India, Papua-New Guinea and Australia. It includes two economically important species: *C. arabica* and *C. canephora*, which represent a major agricultural commodity in world trade. The Rubiaceae is related to the Solanaceae family that contains economically important crop species such as tomato, tobacco, and potato, all being annual. Both families belong to the Asterid clade, and diverged from their common ancestor approximately 83-89 million years ago. Rubiaceae and Solanaceae are frequently considered as "sister" plant families based on genetic similarities observed between coffee and tomato (genome size, chromosome number).

The Vitaceae is an economically important family of angiosperms. It includes the *Vitis vinifera* species, a perennial plant, used as fruit or for beverage production. Recent phylogenetic analyses have placed the Vitaceae family as the earliest diverging lineage of the Rosid clade. Grapevine and coffee diverged from their last common ancestor approximately 114-125 MYA, a long period of evolution that should allow numerous chromosomal rearrangements to accumulate.

So far, very few comparative genome mappings have been performed between distantly related species belonging to two different clades. Extensive pairwise comparative studies have been performed within the Solanaceae and between tomato and coffee. However, no multiple comparisons have been conducted using Solanaceae, coffee and grapevine to study the pattern of chromosomal evolution between species that have not experienced recent polyploidization. Recently, good conservation of the microsynteny was described at one locus between coffee and grapevine. Such microsynteny raised the question of the extent of genome microstructure conservation and the possible presence of macrostructure conservation between distantly-related genomes.

To better understand the structural relationships between the coffee, tomato and grapevine genomes we combined macro- and microsynteny studies to evaluate the genome structure conservation between these distantly-related species. 867 genetically-mapped COSII markers in coffee and tomato identified blocks of synteny with the grapevine pseudo-chromosomes, giving complex and fractioned conservation of genome macrostructure between the three species. Despite extensive chromosomal rearrangements, several large chromosome segments showed good conservation of macrosynteny, shedding new light on chromosome evolution between coffee, tomato and grapevine genomes.

We investigated whether syntenic blocks containing genes of interest might be conserved at the microstructure scale. We found that the ovate region, involved in the fruit shape, was conserved in a syntenic block between coffee, tomato and grapevine. The sequence comparison of this region showed a high level of conservation of genome microstructure between coffee, grapevine and various Solanaceae. However, despite closer phylogenetic distance, lower level of conservation was observed between coffee and Solanaceae than between coffee and grapevine as shown by the frequency and importance of structural variations. These results highlight the fact that even between very distantly-related species belonging to different clades, we may find significant evidence of conservation at the genome macrostructural and microstructural levels. They also indicate that at a particular locus, conservation did not decline in relation to increasing phylogenetic distance, suggesting that the time factor alone is not sufficient to explain chromosomal rearrangements and that it is also probably necessary to consider the generational cycle of the species *i.e.* the number of meiosis. Our results have also proved to be considerably useful for the isolation and rational utilization of important genes for agronomy.

**A 12**

**INTERACTION BETWEEN COFFEE PLANTS AND THE  
INSECT COFFEE BERRY BORER, *Hypothenemus hampei***

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No sources of natural resistance have been identified in *Coffea* species against Coffee Berry Borer (CBB), *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae), the most important coffee pest in Colombia. However, *Coffea liberica* has shown some levels of antibiosis against the insect. In order to understand the interactions between the coffee plant and CBB, to characterize the response of coffee plants under CBB attack and the bases of the *C. liberica* antibiosis, a functional genomics study was carried out using ESTs libraries, cDNA microarrays, and an oligoarray containing 43.000 coffee sequences. The results allowed the comparison of the *C. liberica* vs. *C. arabica* fruit responses to insect infestation after 48h. Out of a set of 2,500 plant sequences that exhibited differential expression under insect attack, 900 were induced in *C. liberica*, at least 2 times more than in *C. arabica*. In order to validate some of the induced genes, quantifications through real-time PCR were done. At least four genes: an isoprene synthase gene, a patatin-like protein gene, a hevein-like protein sequence, and a trypsin inhibitor known also as miraculin-like gene, CoMir, were highly upregulated in *C. liberica* at 24 and/or 48 h after insect infestation compared to *C. arabica*. For each gene, further sequence characterization and comparison were carried out between both genotypes. Functional annotations indicate that they participate in separate defense plant processes such as volatiles synthesis, lipid or chitin degradation, and proteinase inhibition, suggesting the activation of different metabolic pathways and plant defense mechanisms in the coffee plants in response to the insect attack. One of those processes is the methyl-erythritol 4-phosphate (MEP), or non-mevalonate pathway, that leads to the production of isoprene. The effect that isoprene has on the CBB was measured by monitoring the development of the insect from egg to adult, on coffee-artificial diets amended with increasing concentrations of isoprene. Concentrations of isoprene above 25 ppm caused mortality and developmental delay in all insect stages from larva to adult, as well as the inhibition of larvae molting. In conclusion, functional and comparative genomics of coffee accessions allowed the identification of at least one possible mechanism of insect induced response, providing new tools to screen and utilize the genetic resources available, as well as revealing unknown mechanisms of production of volatile substances in the coffee plant with negative effects on CBB that may be applied for pest control purposes and possible interaction with other pests.

## B 6

### INTEGRATION OF GENETIC LINKAGE MAPS FOR *Coffea arabica*

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The genetic map construction in *Coffea arabica* has been a challenge due to the polyploid nature, the low polymorphism rate of the germplasm, especially the ones of interest to breeding, and the absence of a large collection of polymorphic markers for this coffee specie. An alternative to minimize the difficulties to obtain saturated maps and comprehensive coverage of the genome of *C. arabica* is the construction of partial maps, using different populations and classes of DNA markers, and subsequent integration of such maps. With this strategy, we obtained two independent partial maps using  $F_2$  populations, named as H511-1 and H419-1. The mapping populations were chosen based on the polymorphism between the parents and, mainly, in the interest of coffee breeding programs.

A total of 110 molecular markers (31 SSR, 74 AFLP, one RGA and four RAPD) were used for screening 247 plants of the H511-1 population. The partial map developed (map 1) consisted of eight linkage groups (LGs), with 99 markers, covering 1,340.23 centi-Morgan (cM), with an average distance of 14.73 cM between markers. For the other partial map (map 2), the 217 plants of the H419-1 population were genotyped with 125 molecular markers (99 RAPD, 25 SSR and one RGA). Of these, 101 markers were distributed over 13 LGs, covering 1,426.87 cM and an average distance between markers of 16.21 cM.

The existence of 11 loci in common (anchor markers) allowed the integration of the two data sets. It was possible to combine five LGs of the map 1 to six LGs of the map 2. The analysis resulted in a final linkage map with 14 LGs, four of them correspond to the integrated LGs. The other 10 LGs were not integrated due to the lack of anchor markers. The integrated map comprised 188 markers and covered 1,973.35cM of the *C. arabica* genome. The average interlocus distance was 11.34 cM and only 18.97% of the intervals exceeded 20cM. The locus order on the consensus map correlated highly with that of specific maps.

This map was used to identify QTLs involved to coffee leaf rust (*Hemileia vastatrix*) resistance. For this analysis, the plants from the both population were inoculated with race II of *H. vastatrix*. Five QTLs were identified. Two QTL with major effect were detected on LG3 and explain 50.00% and 54.80% of the phenotypic variation. Two minor QTL were detected on LG2 and one on LG4, explaining 7.00%, 9.40% and 9.50%.

A consensus genetic linkage map for *C. arabica* was constructed for the first time and its utility for molecular mapping of QTLs was demonstrated. The maps integration enhanced the genetic resolution and proved to be a promising strategy to obtains a *C. arabica* map that can be used for ongoing and future genomic research such as QTL analysis and positional cloning in addition to marker assisted selection in coffee breeding program. Furthermore, the integration increases the possibility to find informative markers on any part of the genome and in different genetic backgrounds. Financial support: CBP&D/Cafe, CNPq, and FAPEMIG.

## B 5

### INTERNATIONAL HIGH DENSITY COFFEE ROBUSTA GENETIC MAP

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Management of genetic and genomic data for coffee is becoming a crucial step in order to improve the efficiency of breeding for this important agricultural and economic crop for tropical countries.

Genetic map is one of the core genetic resources for synteny study and dissection of complex agricultural or technological traits of importance. Usually, the genetic mapping workflow is starting with a discovery phase where genetic markers, such as RFLPs, SSRs or SNPs, are mined from genomic or EST libraries from different institutes (IRD, CIRAD, Trieste University, Cornell University, Cenicafe and Nestlé). A final step, based on the genotyping of the selected mapping population, is finally performed before the final mapping. Using this classical strategy a first genetic map was obtained on a F1 progeny, performed by ICRRI, using two elite Robusta (i.e. *C. canephora*), highly heterozygous, clones BP409 and Q121, respectively, determined as a Congolese and a hybrid between Conilon and Guinean genotypes. The segregating progeny include 93 individuals which were used to create a genetic map including a first set of 1550 loci covering 1400cM.

A newly developed sequence-based marker technology, Restriction Associated DNA sequencing (RAD-seq), enables synchronous SNP marker discovery and genotyping using high throughput Illumina sequencing. Using RAD sequence data from the segregating population, a total of 1700 RAD markers were added. The final high density Robusta map comprises 3250 loci with an average density close to one marker every 220 kb. Our F1 high density genetic map is being used for genetically anchoring the Robusta genome sequence assembly into pseudochromosomes and facilitating comparative genomic analysis.

Finally, this Coffee genetic map could serve as a bridge to allow identification of loci associated with quantitative traits (QTLs) of interest, thus facilitating the gene discovery or speed up the breeding process. This dense Robusta genetic map is also being used as source of new markers for the development of the Arabica genetic map.

**B 7**

**COFFEE CYSTEINE PROTEINASES AND RELATED INHIBITORS WITH HIGH EXPRESSION DURING GRAIN MATURATION AND GERMINATION.**

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Cysteine proteinases (CP) represent a large group of proteins in plants, with over 140 annotated gene sequences identified to date in the *Arabidopsis* genome. The different CP proteins perform a variety of roles, ranging from an involvement in programmed cell death (PCD), influencing tissue development, to pathogen response signalling. During seed development, cysteine proteinases have been found to participate in PCD events associated with embryogenesis and seed coat formation and in the processing of proteins, particularly the seed storage proteins. Currently, little information exists on the CP genes of coffee, or on the cysteine proteinase inhibitors which influence the activities of these proteinases and may contribute to the tolerance of coffee to one or more insects.

Here, we present two cysteine proteinases (CP) and four cysteine proteinase inhibitor (CPI) gene sequences from coffee with significant expression during the maturation and germination of the grain (bean). Detailed expression analysis of the genes CcCP1 and CcCP4 in Robusta using QRT-PCR show the respective transcripts accumulate primarily during grain maturation and germination/post germination. The corresponding proteins were expressed in *E. coli* and purified, but only one, CcCP4, which has a KDDL/KDEL C-terminal sequence, was found to be active after a short acid treatment. The temporal expression of the CcCP1 gene suggests it is involved in modifying proteins during late grain maturation and germination. The expression pattern of CcCP4, and its close identity with KDEL containing CP proteins, implies it may play a role in protein and/or cell remodelling during late grain germination, and may play a strong role in the PCD associated with the post-germination phase of coffee seedling growth. Quantitative RT-PCR expression analysis of the cysteine proteinase inhibitor genes in Robusta showed that CcCPI-1 is primarily expressed in developing and germinating grain and CcCPI-4 is very highly expressed during the late post germination period, as well as in mature, but not immature leaves. Transcripts corresponding to CcCPI-2 and CcCPI-3 were detected at relatively similar, but generally low levels. The expression patterns suggest that CcCPI-1 could be involved in modulating the grain CP activity; while CcCPI-4 may play roles modulating grain CP activity and in the protection of the young coffee seedlings from insects and pathogens. CcCPI-2 and CcCPI-3, having lower and more widespread expression, could be to be more general “house-keeping” CPI genes. The availability of these characterized gene sequences now enables the mapping of the corresponding genes in the coffee genome and the exploration of possible links between specific CP and CPI alleles, coffee quality and insect resistance.

## B 8

HIGH-THROUGHPUT SEQUENCING OF cDNA SHOWS THAT CV.  
RUBI AND IAPAR59 OF COFFEA ARABICA HAVE DIFFERENT  
MOLECULAR RESPONSE TO WATER PRIVATION.

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It is well known that drought periods affect coffee plant development, leading to plant death and abortion of developing fruits in case of severe drought. In relation to coffee genetic diversity, several works reported the identification of plants of *C. canephora* var. Conilon susceptible or tolerant to drought which were analyzed at the physiological level and also used to identify candidate genes underlying stress responses. Even narrow, a genetic diversity for drought tolerance also exist in the species *C. arabica*. In addition to the identification of undiscovered transcripts, the recent development of low-cost, high throughput next-generation (NGS) sequencing technologies now opens the way to perform expression profiling and to identify gene presenting differential expression patterns by comparing the frequency of reads obtained after sequencing. In order to initiate such kind of approach in coffee, RNA of meristem tissues from Iapar59 (I59, drought tolerant) and Rubi (R, drought sensible) cultivars of *C. arabica* grown under field-grown with (I) or without (NI) irrigation were extracted and used to generate cDNA that were further sequenced. The sequencing data revealed 282.213, 135.304, 345.751 and 230.064 reads obtained from I59-I, I59-NI, R-I and R-NI samples, respectively, totalizing more than 255Mb. These data was compared with all available transcriptome *Coffea* data, including the EST sequences from both *Coffea arabica* and *C. canephora*. The results of these comparisons will be presented as well as the preliminary data of an electronic northern performed in order to identify differentially expressed genes between the two cultivars in both conditions (NI or I). General numbers show that Rubi has a more intense molecular response to drought, with many genes over-expressed. Also functional analysis of biological processes shows an enrichment of stress response genes in Rubi non-irrigated while in I59 there is a decrease in expression in genes related to carbohydrate metabolism and cell wall organization. It is worth noting the number of genes up-regulated in Rubi non irrigated (NI) and involved with drought stress response, like *RD22*, *PDIR10* (dirigent-like protein), *MYB* and caffeine synthase for example, while these genes were not detected under this stress in I59. On other hand, many drought genes related to drought-stress tolerance were detected in the I59 cultivar involved in biosynthetic process such as sugar transporters, some proteins related with abiotic stress tolerance (i.e. osmotins), water channel protein, LEA proteins (implicated in detoxification and alleviation of cellular damage during dehydration) and heat shock proteins (HSPs). In the I59 cultivar, genes coding for enzymes involved in the ABA synthesis (isopentenyl diphosphate isomerase, geranylgeranyl reductase), which causes stomatal closure, precursor and enzymes, were also highly expressed. Q-PCR experiments were also performed and allowed to confirm the data obtained *in silico* for several genes. These results will be presented and discussed.

## B 9

GEOGRAPHICAL GRADIENTS IN THE GENOME SIZE  
VARIATION OF WILD COFFEE TREES (*COFFEA*) NATIVE  
TO AFRICA AND INDIAN OCEAN ISLANDS.

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The *Coffea* genus mainly native to Africa (Eucoffeea and Mozambicoffeea) and to the Indian Ocean islands (Mascarocoffeea), accounts for 124 species. To date, genome size data are only available for 23 African species. The aim of this study was to assess the genome size of 44 Mascarocoffeea species and to investigate possible associations with species geographic distribution, stomata traits and species relationships. 2C values were measured using flow cytometry for which a new procedure using lyophilized leaves was tested. In addition, leaf traits were recorded. The 2C nuclear DNA content of Mascarocoffeea species ranged from 0.96 to 1.41 pg. *C. mauritiana* and *C. humblotiana* having the smallest genomes and *C. dolichophylla* the largest. 2C DNA mean value for Mascarocoffeea was of 1.19 pg and 1.43 pg for Africa. The overall DNA values corresponded to two partially overlapped normal distributions: one harboring species from East Africa and the Indian Ocean Islands, the other harboring species from West/Central Africa. Plotted on a geographical map, according to the native origin of species, these values showed a gradient in Madagascar and in Africa. Genome sizes increased following a North to Southeast gradient in Madagascar and an East to Central-West gradient in Africa. No, or only weak correlations were noted between genome size and stomata parameters. Genetically close species could be highly distinctive in their genome size while divergent species could be similarly sized. The non-random geographic distribution and habitat of species, and the absence of correlation between genome size and genetic relationships, suggest that *Coffea* genomes evolved independently in Africa and in the Indian Ocean Islands following both increase and/or decrease of DNA content. Accordingly, *Coffea* species underwent independent speciation events in both areas.

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**AN INHIBITOR FROM *Lupinus bogotensis* SEEDS EFFECTIVE AGAINST ASPARTIC PROTEASES FROM *Hypothenemus hampei***

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The coffee berry borer, *Hypothenemus hampei* (Ferrari), is one of the most devastating coffee pests (*Coffea arabica*). Digestion in the midgut of *H. hampei* is facilitated by aspartic proteases. Seeds extracts of various plants were evaluated to identify aspartic protease inhibitors. The greatest inhibitory activity of aspartic proteases was found in *L. bogotensis* extract with a specific activity of 74.1 IU/mg, compared with extracts of *H. suaveolens*, *B. humidicola*, and *A. hypochondriacus* that showed a lower inhibition of aspartic proteases. The proteolytic activity of *H. hampei* was inhibited by 90% with 100 µg of crude extract of *L. bogotensis*, whereas it took 1 mg of crude extract of *H. suaveolens* and *B. humidicola* to inhibit the activity at 70 and 60% respectively. This is the first report of purification and characterization of seven aspartic proteases inhibitors from *Lupinus bogotensis* (LbAPI), using a combination of chromatographic methods, which were monitored by measuring the inhibitory activity of the fractions against the aspartic proteases of *H. hampei*. The amino-terminal sequence of LbAPI1, LbAPI2, LbAPI3, LbAPI4, and LbAPI5 showed identity with vicilins and β-conglutins of *Lupinus albus*, suggesting that these proteins could be coded by a family of genes. LbAPI6 and LbAPI7 consist of a polypeptide chain with a molecular mass of 12,86 and 16,91 kDa, respectively; and its amino-terminal sequence has identity with the δ-conglutin of *L. albus*. LbAPI4 exhibited a molecular mass of 12,84 kDa and a single polypeptide chain. LbAPI4 was stable at 70 °C and pH range, 2-11 at 30 °C. In *in vitro* assays, LbAPI4 was highly effective against aspartic proteases from *H. hampei* guts with a IC<sub>50</sub> of 2,9 µg. LbAPI4 inhibits pepsin at a stoichiometric ratio of 1:1 and a K<sub>i</sub> of 3,1 µM. Its amino-terminal sequence had 76% identity with vicilin and β-conglutin. The gene that codes LbAPI4 inhibitor corresponds to a sole open reading frame of 354 nucleotides that code for a polypeptide of 117 amino acids and have no introns. Amino-terminal sequence of LbAPI was used to amplify the entire open reading frame of the gene from total seed DNA and the complete coding sequence of LbAPI4 was cloned in pET-15b expression vector of *Escherichia coli*. The recombinant LbAPI4 produced 98% mortality to *H. hampei* when incorporated into an artificial diet at a level of 1.5%. The mortality of larvae fed with 1% LbAPI4 was 51%. This suggests that LbAPI4 may be a promising tool to make genetically modified coffee with resistance to *H. hampei*.

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## ANALYSIS OF THE EXPRESSION PATTERN OF miRNAs, BY STEM-LOOP RT-PCR, IN COFFEE SPECIES WITH DIFFERENT PLOIDY LEVELS.

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Polyplody is a remarkable genetic trait in eukaryotes, particularly in plants. Most angiosperms experience one or more polyploidization events in their lineage. Although the frequent occurrence of this process suggests that there is an evolutionary advantage of having several sets of genetic material for adaptation, polyploidization events may induce genomic shock. Studies in numerous species have shown that silencing RNAs, especially microRNAs, small interfering RNAs, trans-acting siRNAs and natural antisense siRNAs, may act as «genetic buffers». Through silencing or over-activation of their target genes, the small RNAs influence decisively in most cellular processes involved in the functionality and stability of hybrids. In an innovative way, we analyzed the expression pattern of some microRNAs in coffee. The stem-loop RT-PCR assays with *Coffea arabica* tetraploid species and *Coffea canephora* diploid species, showed that the number of small RNAs corresponding to miRNAs increased according to the ploidy level. Evaluating the additive gene expression model, in *Coffea arabica* the chromosome number is  $2n = 4x = 44$  and the accumulation of microRNAs corresponded to approximately twice the values found for *Coffea canephora* ( $2n = 2x = 22$  chromosomes). In the case of allopolyploid, additive expression may provide the molecular basis required for compensation and balancing of the extra amount of redundant genes allocated in a single nucleus.

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**PA 305**

**RESTRUCTURED SAMPLING PLAN ENABLES THE  
CHARACTERIZATION OF MORE VIRULENCE GENES OF  
*HEMILEIA VASTATRIX* IN KENYA**

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Arabica coffee was introduced in Kenya about 1900. The crop spread across the country both as commercial cultivation and germplasm conservation plots. The first report of coffee leaf rust (*Hemileia vastatrix* Berk. & Br.) in the country was made in 1912 and breeding for resistance against the disease has been a priority. In addition to conventional *Coffea arabica* L. varieties, derivatives of Timor Hybrid (HDTs) that are natural hybrids between *C. arabica* and *C. canephora* Pierre ex Froehner have been introduced into the country and used in breeding programmes since early 1960s. The HDTs received major genes responsible for rust resistance ( $S_{H6}$ ,  $S_{H7}$ ,  $S_{H8}$ ,  $S_{H9}$  and others not yet identified) present in *C. canephora* germplasm introgressed into *C. arabica*. New virulence genes and/or races of the pathogen have not been reported among rust samples collected from the country since 1977, when four virulence genes (v<sub>2</sub>, v<sub>3</sub>, v<sub>4</sub> and v<sub>5</sub>) were identified. This evidenced the urgent need of redesigning the survey strategy in order to increase the chances of detecting new races of the pathogen. Sampling was therefore conducted targeting coffee germplasm conservation plots, breeding fields and commercial farms planted with mixed coffee varieties. The samples were characterised at the Coffee Rusts Research Centre (CIFC), Portugal, and the results revealed three new virulence genes (v<sub>1</sub>, v<sub>7</sub> and v<sub>8</sub>) with the possibility of a fourth one (v<sub>9</sub>). The virulence genes v<sub>7</sub>, v<sub>8</sub> and v<sub>9</sub> are able to overcome the resistance genes derived from HDTs and this presents a threat to the resistant varieties being developed. This presentation discusses the outlook possible implications of such a status.

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## NEW CYTOLOGICAL AND MOLECULAR DATA ON COFFEE-COLLETOTRICHUM KAHAWAE INTERACTIONS

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*Colletotrichum kahawae* is the causal agent of coffee berry disease (CBD), the most devastating Arabica coffee disease in Africa at high altitude, and represents an imminent threat for cultivation in America and Asia. In Kenya, the hybrid commercial variety, Ruiru 11, was bred for resistance to CBD and coffee leaf rust. Its female parent consists on lines of the cultivar Catimor (from Colombia) selected for resistance to both diseases in Kenya. One such line is Catimor 88, which is still being used in breeding programmes. Molecular studies using a F2 mapping population of the susceptible cultivar SL28 and the resistant line Catimor 88, identified and mapped a major gene (Ck-1) responsible for resistance to CBD.

In this study we aimed to start the cytological and molecular characterization of *C. kahawae* interaction with Catimor 88 vs a susceptible coffee variety (Caturra). When challenged with *C. kahawae*'s isolate Que2 (from Kenya), the majority of Catimor 88 hypocotyls presented scab lesions, whereas hypocotyls of the variety Caturra exhibited dark sunken lesions with sporulation, five to six days after inoculation. Light microscopic studies showed, in the susceptible genotype, the fungus growing without apparent inhibition and feeding on living host cells (biotrophy) before switching to necrotrophy. Reversely, in the resistant genotype fungal growth was frequently restricted to a single epidermal cell and plant response occurred early with accumulation of phenolic compounds and deployment of hypersensitive-like response (HR).

Gene expression studies using quantitative real time PCR (RT-qPCR) are currently being developed to characterize these interactions. This is a sensitive technique for quantifying gene expression, and its success depends on the stability of the reference genes used for data normalization. To our knowledge this is the first study on validation of coffee reference genes during *C. kahawae* infection time-course. Eight candidate reference genes (namely *ubiquitin* and *gapdh*) were selected and their expression stability is being evaluated by qRT-PCR in healthy and infected tissues of Caturra and Catimor 88, at 12h, 48h and 72h after inoculation. NormFinder and geNorm algorithms will be used to select the appropriate reference genes. Validation of such qRT-PCR reference genes will be discussed as the basis for the following gene expression analyses regarding this pathosystem.

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**PA 307**

**RELATIVE INFLUENCE OF PLOT AND LANDSCAPE SCALE  
FACTORS ON COFFEE BERRY BORER ABUNDANCE: A VARIATION  
PARTITIONING HIERARCHICAL APPROACH**

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Pests and diseases are under the influence of multiple factors that act at plot and landscape level. Romero *et al.* (2011) demonstrated that the coffee berry borer (*Hypothenemus hampei*; Coleoptera: Curculionidae) abundance in coffee plots was positively correlated to the proportion of coffee area in the landscape, possibly because coffee berry borer survival was improved during postharvest period in landscapes with more resources. On the contrary, proportion of other land uses in the landscape, as forest, pasture and sugar cane, were negatively correlated to the pest abundance. This raises the question of the importance of landscape effects on the pest, compared to known plot scale effects on which control practices are based. We used data from Romero *et al.* (2011) where 50 geo-referenced coffee plots, from Turrialba, Costa Rica, were characterized for their management, environmental, plant status and landscape attributes, as well as for the coffee berry borer abundance. We quantified the relative influence of local factors, landscape context and spatial distance between plots on coffee berry borer by using variation partitioning techniques and generalized hierarchical models (Legendre, 2008). Our results indicate that environmental and landscape variables explain the highest proportion of coffee borer abundance variation (individual fractions: 22% and 17% respectively). However, when assessing the unique contribution of each variable, the number of remaining infested coffee fruits per tree after harvest was the most important variable with 22% of the coffee berry borer abundance variation explained, followed by the number of fruiting nodes (16%), altitude (associated to temperature, 13%), and in a lesser degree, shade type (11%), spatial dependence between plots (9%) and proportion of pasture in a 400 m radius (7%). Spatial dependence indicates that pairs of coffee plantations at a distance smaller than 450 m have similar coffee berry borer infestations, suggesting exchanges of populations between coffee plots under this distance. Our results indicate that picking infested coffee fruits remaining after harvest is the most important cropping practice for the control of coffee berry borer. However landscape context attributes explain coffee berry borer abundance, their low contribution to the total variation of the pest abundance suggests that control practices at landscape scale should only have slight effects on coffee berry borer abundance.

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Legendre, P., 2008. Studying beta diversity: ecological variation partitioning by multiple regression and canonical analysis. Journal of Plant Ecology 31:976–981.

PA 310

## IDENTIFICATION OF THE VULNERABILITY OF COFFEE FARMERS' LIVELIHOODS AND DEVELOPMENT OF ADAPTATION STRATEGIES TO CLIMATE CHANGE IN MESOAMERICAN

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According to the Intergovernmental Panel of Climate Change (IPCC) report, Mesoamerica is one of the regions that will suffer severe impacts from a progressively changing climate. Coffee production is the mainstay of thousands of families and the major contributor to the agricultural GDP of these countries, hence vulnerability assessments are of vital importance to identify adequate adaptation strategies. Nicaragua, El Salvador, Guatemala and Mexico were investigated in the present paper.

Vulnerability was defined considering three factors: exposure, sensitivity and adaptive capacity. Exposure was determined by modeling coffee production suitability (current and future) for the A2a emission scenario (business as usual) using twenty downscaled Global Circulation Models (GCM) in combination with Maxent and Ecocrop crop prediction software. Focus groups and an expert panel were used to develop indicators for sensitivity and adaptive capacity which were field validated by 558 semi-structured interviews with coffee households. Participatory workshops were carried out aiming at the development of prospective guidelines towards climate change adaptive capacity. Nine indicators were validated for sensitivity and eleven for adaptive capacity.

Through the combination of exposure with the indicators of sensitivity and adaptive capacity, vulnerability was identified for coffee producers in the four countries. High exposure was defined as suitability loss of coffee production by 2050. Coffee farms will lose suitability between 20-81% in El Salvador, 20-59% in Nicaragua, 24-47% in Guatemala, and 25-45% in Mexico. High sensitivity and low adaptive capacity were evaluated considering livelihood capitals, whereby coffee productivity level and post-harvest infrastructure were identified as the most determining indicators in all countries. Additionally, in Nicaragua and Mexico migration was identified as important. Furthermore, in Nicaragua, El Salvador and Guatemala, low access to technologies, education and organization level are very important. A common characteristic of all farmers was a high income dependency on coffee (50-55%), corn and beans (20-30%).

The families of the four countries identified the following adaptation strategies to climate change: Conservation and planning of sustainable management of the resources, diversification of crops in areas with coffee suitability loss, raise of the level of access to education, sensitization of key actors in conservation, organizational strengthening, capacitation through participatory action research and creation of financial credit programs. However, the analysis suggests that strategies must consider policies and the families' geographical location, and access to and availability of resources.

Key words: Vulnerability, livelihoods, climate change, exposure, sensitivity and adaptive capacity

## A 1

### THE CHANGING CLIMATE FOR SUSTAINABLE COFFEE

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There is growing evidence that climate change is affecting coffee production; the lower limit for growing coffee is clearly rising in some countries, the proportion of Robusta to Arabica is increasing in others and reports of extreme weather encountered by coffee farmers are becoming common.

Quantitative scientific data on the extent of the effects however is largely missing. We understand physiological thresholds of the coffee tree, but cannot predict where and when major short to medium term climatic events will occur. We have ideas to help farmers cope but the cost-benefit of changes such as increased shade are not well understood for specific localities. We also do not know how much coffee land is disappearing at the lower margins and how much new land is entering into production in other places. Such data is needed by the coffee industry to plan long term sustainable production and an estimate of global carbon footprint and flux is needed if the industry is really serious about reducing carbon emissions.

Climate change poses a severe challenge to our current concepts of sustainable coffee production. Over the past two decades various sustainable schemes have arisen to provide the consumer with ethical and environmentally friendly products. These schemes however were designed and instigated before the threat of climate change became apparent and this presentation argues that a major rethink is now required if they are to cope with rapidly changing conditions in the field. There are two main reasons – scale and time:

- 1) Scale: the farm is the unit of certification, but various environmental challenges can only be partially combatted at the farm level. Certifications do not deal with wider problems such as depletion of ground water (e.g. Vietnam), erosion and landslides (e.g. Uganda), proliferation of diseases (much of Africa) and deforestation (e.g. SE Asia).
- 2) Time: over the past ten years certified coffee has grown from 1% of global sales to 10%. But during that period volume of coffee produced has increased by more than this, with much of the extra supply coming from newly planted land, some of it deforested.

Thus the current commercial trends in sustainability are too small and too slow to cope with the level of change now becoming apparent in many coffee countries. A shift away from the farm scale towards landscape scale issues that identify and remedy major limiting factors to production is now needs to be considered. The presentation will suggest some ways in which this can be tackled and suggest that a radically different approach by the coffee industry is needed if it is to remain as a leader in sustainability issues as it endeavours to satisfy increasing demand from an eventually diminishing global coffee area.

**A 2**

## **INTEGRATED CLIMATE CHANGE IMPACT MODELING OF THE COFFEE SECTOR INDICATES MIGRATION OF PRODUCING REGIONS AND PRESSURE ON ECOSYSTEMS**

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Various biophysical impact models project a highly negative impact of climate change on the coffee crop with the likely result of reduced global yields. As plantations have a lifespan of several decades adaptive action must be pro-active and needs to be initiated now. Thus, there is a need for research that effectively guides adaptation policy. Such climate change impact assessments must include global market feedbacks into the analysis to enable the prioritization of adaptation pathways based on economic efficiency considerations.

This work represents the first integrated climate change impact assessment for the coffee crop using a combination of agro-ecological niche modeling and the global recursive dynamic partial equilibrium model GLOBIOM. The GLOBIOM model has been designed to provide policy analysis concerning land use competition between major land-based production sectors such as agriculture, bioenergy and forestry. It combines spatially explicit information on land uses, agronomic and forestry potentials as well as production costs with regional demand and bilateral trade flows. Into GLOBIOM we integrate a two product model of the coffee sector that distinguishes between Arabica and Robusta green beans. Future demand scenarios are derived from population growth and economic growth projections of the climate change emission scenario projections (SRES). The model is calibrated based on current climatic suitability, production and trade patterns, and data for alternative land-uses. Yield potential and spatial allocation of coffee production are modeled using ecological niche theory derived climate suitability maps. This approach allows for a straight forward modeling of future climatic stress.

We analyze the shift in global production patterns and trade flows by 2030 and 2050 under different climate and demand scenarios. As climatic conditions for coffee become less favorable, average prices and total area under coffee production increase. Brazilian Arabica production is reduced due to the adverse climate change impact while African and Central American producers become increasingly important. The share of Robusta production on world markets increases. As future suitability scenarios project relatively favorable conditions for coffee production in higher altitudes forest ecosystems are increasingly under pressure. The resulting deforestation represents a positive climate change feedback mechanism that counteracts mitigation efforts.

Drawing from our impact analysis we discuss possible climate change adaptation policy scenarios. We call for the development of strategies that increase the resilience of the coffee crop under increased heat, and temperature and precipitation variability. Furthermore, impact mitigating migration strategies need to be drafted in order to facilitate transition to crop alternatives in regions where coffee production is likely to be abandoned, and to make use of opportunities where coffee production may become feasible, while protecting natural resources.

## A 3

### GLOBAL IMPACT OF CLIMATE CHANGE ON COFFEE SUITABILITY

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The fact that climate change will have an adverse impact on agriculture is now uncontested. Various studies show that the exposure of coffee systems to climatic changes will result in decreased suitability, yield, inferior quality and increased pest and disease pressure. This is commonly related to changes in temperature and precipitation patterns. To date, no global study on the impact of climate change on coffee production exists.

To assess the impact of climate change on coffee suitability globally we first quantified changes in predicted climate patterns by 2030 and 2050 using 18 Global Circulation Models (GCM). Then, we modeled the potential world coffee distribution using the Maxent crop prediction program training it on over 5200 unique coffee evidence locations worldwide. This model is widely acknowledged to yield the most accurate results. Finally, we projected the model to future climate data using Global Climate Models (GCM) to identify the level of exposure of coffee suitability to Global climate change. As climate input data we used 19 bioclimatic variables from Worldclim (current climate) and 18 GCMs (future) under emission scenario A2 and on 2.5 arc-minutes (approximately 5 kilometers) scale.

Our approach yields a detailed spatially explicit crop suitability map for current climate conditions, as well as for future conditions. The current crop suitability map is verified by randomly holding back a 25% subset of the unique presence locations. Results indicate a low rate of omission and commission errors, the map thus accurately represents current coffee presence. The comparison with the map of future suitability for coffee production indicates significant losses of suitable area.

We examine drivers of suitability changes and find that areas that lose suitability can be found at lower altitudes around a mean of 800m.a.s.l. While coffee at latitudes between 10°N and 10°S is impacted by higher temperatures, at more extreme latitudes this is further aggravated by reductions in annual precipitation resulting in suitability losses of up to 80%. In contrast, areas that gain see only modest improvements of up to 40% in suitability. These areas can be found at a mean of 1900m.a.s.l. mostly between 10°N and 10°S. Climatic changes are similar for these regions but nevertheless result in improving conditions. Outside of the 10° circles of latitude gains in suitability can hardly be observed due to the lack of high areas.

Thus, our model reveals drastic losses of coffee area in low regions at high latitudes. Our work implies a concentration of future production around the equator, where some areas also gain in suitability. However, our model implicitly assumes unchanged cultivation practices. We therefore conclude that coffee research must focus on developing new means that address the coming changes. Our results are expected to serve as an analysis tool for future projects related to socioeconomic, vulnerability and political analysis of the adaptation of coffee production.

**A 4**

**GREENHOUSE GASES EMISSIONS OF GREEN COFFEE  
PRODUCTION IN THE STATE OF MINAS GERAIS, BRAZIL:  
MEASUREMENT AND MITIGATION**

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In recent years, the debate about environmental impacts and the sustainability of agricultural products has increased. Consumers are more and more concerned about the quality of food products and now looking for those with a low environmental impact, with a particular attention to carbon emissions. There are few studies regarding the greenhouse gases emissions associated with the Brazilian green coffee production. Located in the southeast region, Minas Gerais is the largest coffee-growing State in Brazil. It accounts for nearly 70% of the national coffee production. The objective of this study was to determine the main greenhouse gases (GHG) sources and to measure the carbon footprint of coffee production in the State of Minas Gerais. Three coffee farms located in the three typical production regions of Minas Gerais were selected: Cerrado Mineiro (CM), Matas de Minas (MM) and Sul de Minas (SM). Data from crop years 2009/2010 and 2010/2011 were considered. The carbon emission sources considered within the coffee farm were mobile and stationary combustion, nitrogen and organic fertilizers, lime and electricity. The upstream emissions related to the production and transport of agricultural inputs have not been accounted. Total emissions were different in the three different regions. However, besides the total emissions during a crop year, it is important to consider the emissions per unit of green coffee and per area cultivated with coffee in order to give a more accurate representation of the impacts in the production system. Total emissions have been therefore weighted by quantity of green coffee produced and by production area. Results show that the major source of carbon emissions was nitrogen soil fertilization. Fuel consumption for farm operations and lime application are also shown to be important. Electricity was not significant as most of the energy supply in Brazil comes from low GHG emission sources (e.g. hydroelectric and biomass). Additionally, some mitigation strategies related to nitrogen fertilization were proposed, such as the substitution of urea for lower GHG emission sources (e.g. ammonium nitrate) and the correction of fertilization rates and methods. This study is to be considered as a pioneering initiative in Brazil and it intends to provide baseline carbon footprint data, upon which emissions reduction plans and further research can be built. With these results it will be possible to design management strategies to promote sustainability along the coffee production chain and to add value to the final product.

**A 5**

## **MEASURING THE CARBON FOOTPRINT IN COFFEE PRODUCTION SYSTEM**

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Sustainability and profitability of Colombian coffee with a harmonic relationship with the environment, has been one of the most important objectives of the National Federation of Coffee Growers of Colombia (FNC). In accordance with the above and in line with global concern about climate change, Colombian coffee environment can actively contribute to mitigate the increase of greenhouse gas (GHG) emissions through the reduction of emissions associated with the agroindustrial production process of coffee.

Specifically, through the production system of dry parchment coffee in a coffee farm, there are different processes and stages which generate fixations and emissions of major greenhouse gases (carbon dioxide - CO<sub>2</sub>, methane - CH<sub>4</sub> and nitrous oxide - N<sub>2</sub>O). For the development of the coffee plant, as all plant, converts the sun's energy into biomass by fixing CO<sub>2</sub> through the photosynthesis process. The total biomass produced, between 15% - 20% is located in the coffee beans, and in turn nearly 50% is carbon. Each year the biomass is removed from the fruits, leaving between 80% - 85% of the total biomass produced and also the carbon held in trees, which continue with their growth and accumulation.

For the intrinsic activities of coffee production, as in any productive activity, it is necessary to carry out tasks that have implicit in major or lesser extent the expenditure of energy and the generation of emissions.

For each of the system production processes, can be calculated fixations and / or GHG emissions from the scientific and technological information generated by CENICAFE and supplemented by emission factors presented in the literature.

The growth and carbon fixation by the coffee and other associated species, were calculated from functional models through Creft ® platform (Riaño et al, 1996). This latter allows the calculation from the bid climate, population density and plant age. At the net energy balance and carbon plantations are removed the emissions associated with agricultural activities of the culture in all its aspects and then those related to harvesting and post harvest. The carbon footprint measurement, allows identifying critical points in which the coffee production system must improve its energy performance in order to reduce its footprint, contributing as an active and effective part to the mitigation of global warming by reducing the emissions of GEI, associated with this component of the agroindustrial cycle.

## A 6

### VIETNAM COFFEE SECTOR REVIEW AND PERSPECTIVE

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Vietnam's coffee sector could be considered as a success story of trade liberalisation in agriculture in Vietnam because it supports heated competition among various players of all economic sectors. Bold reforms in the late 1980s and early 1990s have really triggered the booming of the coffee sector in the Vietnam. Between 1990 and 2009, the national coffee production increased more than eleven times, the coffee growing area expanded by more than four times. Coffee has become one of the most important agriculture products and export item of the country. The country is now the world leading exporter of Robusta coffee. Coffee is clearly the most vibrant livelihoods for many rural households. However, the current coffee production in Vietnam shows many problems that include aspects from institutional organization, production, climate change, financial sources and environment. These issues lead to low productivity, aging, poor quality, abuse of fertilizer and pesticides, deforestation and abuse of water system. Especially, coffee production in Vietnam is facing a number difficulties and challenges. First of all, from now until 2015, about 40% of coffee trees will grow old. After this period, the coffee productivity will be reduced in due course. Therefore, the rejuvenation program for coffee is being applied in Vietnam. In addition, the traditional production practices are over input use, lacking facilities for preliminary processing, insecure coffee garden forcing farmers picking all the coffee beans at the same time. And the institutional arrangement especially among small scale farmers is also one challenge that limit the application of technology, unifying of products quality and so on. This all leads to the poor quality of the coffee produced in Vietnam.

That's the reason why over the last decade, a number of coffee sustainable program have been implemented in Vietnam. At the moment, 4C, Utz, Fair Trade and Rain Forest Alliance are the 4 main coffee sustainable standards implementing in Vietnam. This presentation will focus on the current implementation process of these 4 standard sets in coffee production in Vietnam.

However, those sustainable efforts are still separate and have been done by mainly enterprises involving in coffee trading and processing in Vietnam. Only Dak Lak province (the biggest coffee producing area in Vietnam) has issued the coffee sustainable program of the province. Other provinces have not issued any program for sustainable production. At national level, there's no sustainable program yet. So in the coffee strategy which is now in the process of drafting, coffee sustainable production stays in the main focus to mobilize resources from the government, development agencies, enterprises.

These require the government and related stakeholders to develop and implement a sound and feasible strategy so that the coffee sector could be growth in the sustainable way. The objective of the strategy is increased sustainable coffee production in a pre-competitive manner, and coffee farmers being more resilient, in terms of both capacity building and good social and environmental practices. This presentation will therefore make the review of Vietnam coffee sector and present the ways and directions forward.

## B 3

ASSISTED-SELECTION OF NATURALY CAFFEINE-FREE  
CULTIVAR: SNPs CHARACTERIZATION

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The search for caffeine-free or low-caffeine coffee plants has been used as an alternative to meet demands of decaf market without loss in cup quality. The knowledge regarding the synthesis and degradation of caffeine has great relevance in studies aiming to develop caffeine-free coffee grains, either by molecular intervention to control the biosynthesis, or by use of molecular markers genes for assisted selection in breeding programs. In this study, progenies from  $F_2$  and  $F_1BC_1$  populations involving the caffeine-free mutant AC1 were evaluated using molecular tools. The main objectives were to understand the genetic basis of this mutation, and to develop strategies to assist breeding of new caffeine-free cultivars. *In silico* analysis of caffeine synthase gene sequences from both normal and mutant genomes were performed, and two candidate SNPs were selected for further analyses. Total DNA was extracted from 234 progenies and allele discrimination was performed by Real-time PCR, using specific primers and probes designed for each SNP. These analyses allowed the identification of plants bearing the mutated allele (SNP1.1 e SNP2.1) and those with the normal allele (SNP1.2 e SNP2.2). The genotyping results were correlated with HPLC analyses of caffeine content from evaluated progenies, and the correlation index was satisfactory for a reliable discrimination of caffeine-free genotypes. These results open the possibility to correlate molecular analyses (qPCR) with analyses of caffeine levels (HPLC), enabling the use of two SNPs as a selection tool for the decaf trait, and allowing the anticipation of plant selection among progenies under evaluation.

## A 8

## CLIMATIC FACTORS DIRECTLY IMPACT THE BIOCHEMICAL COMPOSITION AND THE VOLATILE ORGANIC COMPOUND FINGERPRINT IN GREEN ARABICA COFFEE BEAN AS WELL AS COFFEE BEVERAGE QUALITY

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This study was aimed at determining whether climatic conditions during bean development affected the chemical composition of the seed, the sensory perception of the coffee beverage and combinations of volatile compounds in green coffee. Using 16 experimental plots in Reunion Island displaying broad climatic variations, we showed that chlorogenic acids and fatty acids in the seed were controlled by the mean air temperature during seed development. By contrast, total lipid, total soluble sugar, total polysaccharide and total chlorogenic acid contents were not influenced by climate. Glucose content was positively affected by altitude.

The results revealed that, among the climatic factors, the mean air temperature during seed development greatly influenced the sensory profile. Positive quality attributes such as acidity, the fruity character and flavour quality were correlated and typical of coffees produced at cool climates. Volatiles were extracted by solid phase micro-extraction and the volatile compounds were analysed by GC-MS. Two alcohols (butan-1,3 diol and butan-2,3 diol) were closely correlated with a reduction in aromatic quality, acidity and an increase in earthy and green flavours. We assumed that high temperatures induce accumulation of these compounds in green coffee, and would be detected as off-flavours, even after roasting. Climate change, which generally involves a substantial increase in average temperatures in mountainous tropical regions, could be expected to have a negative impact on coffee quality.

A 24

ENVIRONMENTAL AND SOCIAL STANDARDS: THEIR IMPACT  
ON FARM AND COOP PERFORMANCE IN NICARAGUA**HAGGAR, J.\* , HOCDÉ, H.\*\*, LE COQ, JF.\*\*, SOTO, G.\*\*\*, JEREZ, R.\*\*\*, MENDOZA, R.\*\*\*\***

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In Nicaragua at the end of the 80's coffee exports were managed by the state, but from the coffee marketing cooperative movement was formed. By 2010/2011 73 companies were exporting coffee of which 25 were cooperatives representing nearly 20,000 producers. Data from the Centre for Export Procedures reports a considerable increase in exports from cooperatives up from 10% in 2006/07 to 19% on 2010/2011. The cooperatives have the productive potential to export up to 22% of national production, but are financially limited in their ability to collect all the coffee from their members. In the last harvest the FOB prices from cooperative exports were 11% higher than for the two main multinational exporters. Being protagonists and founders of the Fairtrade movement and the integration of organic certification for many members was fundamental to the establishment of the cooperatives. Later they have diversified into other sustainable markets with Rainforest Alliance, C.A.F.E. Practices and Utz certified. Although always quality has been more important than the certification to the markets. Above all the cooperatives have sought to sell directly to roasters.

However the question remains "How effective are the certifications at discriminating between farms with different environmental management practices and conditions?" To address this question 294 coffee farms (both cooperative members and independent farms) were surveyed in the main coffee growing region of Nicaragua divided between 5 certifications (C.A.F.E. Practices, Fairtrade, Organic, Rainforest and Utz certified) and conventional farms. The survey was conducted using the COSA (Committee on Sustainability Assessment) methodology. As regards the characteristics of the shade there was no significant difference in the density of trees, but organic, Fairtrade and Utz had greater species richness (when normalized for farm size) and more tree strata, but these characteristics were also associated with small farms. Estimates of area eroded in the plantation was significantly lower for organic (4%) than other certifications and conventional (8-14%), while in general certified farms were associated with application of soil conservation practices compared to conventional farms. Practices to manage water contamination were associated with Rainforest Alliance, C.A.F.E. Practices, and Utz certified farms (and larger farms), but not with Fairtrade, conventional or in general small farms. In general certifications were associated with different environmental characteristics, but these were also a function of the typical farm size being certified.

Ultimately the sustainable environmental certification of the product appears to be of lesser impact than the development of a cooperative movement in reducing poverty and improving the livelihoods of producer families through the increasing demand for specialty coffee.

**A 7**

## **DEVELOPMENT AND RELEASE OF COFFEE BERRY DISEASE RESISTANT VARIETIES TO SPECIALTY COFFEE PRODUCING REGIONS IN ETHIOPIA**

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### **Abstract**

Ethiopia is acknowledged for the production and supply of world renowned specialty coffees among which Harar, Sidamo, and Yirgacheffe have been trademarked and licensed by a number of importing and roasting companies like Starbucks and Caribou. The demand for these fine coffees has been tremendously increasing in the specialty market although the crop yield is apparently dwindled due mainly to major diseases like coffee berry disease (CBD) and vascular wilt. With the objectives of developing disease resistant specialty coffee varieties and boost the yield with their specific quality profile of origin, a multidisciplinary research program (for disease resistance, yield and quality) have been designed and implemented between 1997 and 2010. During these periods, a large number of mother coffee trees were selected from Sidamo and Yirgacheffe/Gedeo (76), Wollega (81) and Hararghe (60) and their seedlings were planted out in a single tree progeny plot (6 – 10 tree/plot) at the respective regions for preliminary evaluation for disease resistance (CBD, CLR and CWD), quality and yield. Based on three to four years data, the most promising 13 selections were promoted to verification trials and planted (20 - 75 tree/plot) in at least two farmers fields at respective original areas with randomized complete block design (RCBD) with three replication. With regard to diseases, the coffee selection were intensively tested for CBD, wilt and leaf rust resistances under field conditions. The attached berry test (ABT) for CBD resistance and seedling inoculation tests for both CBD and CWD were employed to assess and prove the resistance of all the promising selections under field and controlled growth room conditions.

Based on their results of greenhouse and field evaluations, a total of the best eleven CBD resistant coffee varieties, some of which with multiple reactions, were developed and officially approved for production in the major specialty coffee growing regions of Ethiopia in 2010. These included three varieties namely, 971 'Fayate', 974 'Odicha' and 85257 'Koti' for Sidamo/ Yirgacheffe, four varieties W66/98 (Haru-1), W76/98 (Challa), W92/98 (Sende) and 78/84 (Menesibu) for Wollega/Ghimbire; and four varieties H674/98 'Harusa', H739/98 'Mocha', H823/98 'Mechara-1' and H857/98 'Bultum' for Hararghe areas. The overall mean percentage of CBD infection on Wollega varieties varied from 11 to 15 in ABT in the field (progeny and verification plots); while Harar varieties have shown less than 10% infection in verification trials at Hararghe with contrasting values ranging from 13% to 45% in progeny plots at Jimma. The Sidama/ Yirgacheffe coffee varieties had the best performance for possessing moderate to high levels of multiple resistances to both CBD and CWD (< 10 %) CWD infection. These released resistant coffee varieties possess better yield and typical quality profiles of their origin like 'fruity', 'floral'/spicy', and 'Mocha' for Sidamo/Yirgacheffe, Wollega and Harar specialty coffee, respectively. respectively.



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## ORAL SESSIONS

**Thursday, November 14, 2012**



**A 11**

**COFFEE PESTS IN A CHANGING WORLD**

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Global and local environmental changes and their forecasted impact on coffee production will ultimately have serious implications for livelihoods and poverty levels throughout the tropics if no far-reaching measures to adapt to the changing conditions are implemented. Changing environmental conditions will most likely affect coffee production by disrupting this complex agro-ecosystem as a whole, by not only directly disturbing the coffee plant and its productivity, or by reducing or shifting the land suitable for coffee production, but also by affecting the dynamics of its pests and diseases, causing more serious and frequent outbreaks. Higher trophic levels (like pests and their natural enemies) are known to be more affected by changing environmental conditions and habitat modifications than the first trophic level (the plants). As a result, environmental changes will exert their effects on coffee production by first influencing pests and natural enemies, possibly disrupting their relationships. Thus, global environmental changes are likely to directly influence the dynamics of all trophic levels by modifying the setting of species' range limits and leading to expansion or range contraction. Climate parameters have a strong and direct influence on insects' bionomics, reproduction and survival, on the number of pest generations per year, phenology and distribution range. A change in climate may have significant effects on a multitude of interactions between species and seemingly minor changes of individual interactions can exert important effects on the structure of entire communities. Little research has been done in coffee production areas on the impacts of changing environmental conditions and land use change on functional agro-biodiversity (including work on insect pests) and their interactions/impacts on crop production. Changing environmental conditions do not only include an increase in the mean temperature of the planet but also changes in temperature and water balance derived from changes of land use.

There is a need to fill some of the climate change knowledge gaps in the coffee-production sector, and to assist in the development of adaptation strategy packages for changing environmental conditions with special emphasis on management of insect pests and diseases. Possible adaptation strategies to changing environmental conditions in the coffee system are discussed.

**B 10**

**GENOMICS TO OVERCOME CLIMATE CHANGE  
IN THE CONTROL OF THE COFFEE BERRY  
BORER, *Hypothenemus hampei*, IN COLOMBIA**

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Field research has clearly demonstrated the effect of climate conditions related to altitude in Colombia on the dynamics of Coffee Berry Borer (CBB). Coffee crops located at an average temperature over 21 °C proved to benefit the reproduction of the insect and its ability to damage up to half the production of coffee beans in a harvest period. Due to this fact, and the probabilities of having a rise in temperature in the years to come, there has been a need to develop genomics strategies to control CBB as a way to overcome climate change. We have advanced in the understanding of the genetics of CBB in lab and field conditions; have started a CBB genome sequence initiative using 454 pyrosequencing of Whole Genome Sequence libraries, 8K and 20K paired-end libraries, and a Focusing Genome Sequencing strategy for assembling in order to identify genes; standardized a transposon-based germ-line transformation of CBB for functional genomics; and developed a mathematical model to simulate CBB populations and its dispersal in the field in a novel approach to genetically control CBB. The results of these studies have confirmed the ability of CBB to outbreed in field conditions, giving the chance to explore a strategy to introduce deleterious genes in an established field population as an autocidal genetic control strategy. To do so, harmful genes must be identified. We now have a first draft CBB genome sequence and are examining the more than 20,000 genes that compose it. In doing so, we have found genes involved in every biological procedure in the insect, and we have found that a previously identified gene, *Rdl*, that provides CBB resistance to insecticides, also gives CBB a low capacity to reproduce and a higher rate of survival. We have pursued lab and field tests in order to obtain life tables of these mutant CBBs and to recognize their capacity to infest coffee berries. We have successfully genetically transformed CBB using transposon-based gene vectors in order to use this technology to find new interest genes. We now have four transgenic CBB lines, one containing *piggyBac* 3xP3ECFP and three pMinos 3xP3DsRed at the University of Maryland. A CBB mathematical model has been developed and validated, and a molecular marker-based dispersal technique has been designed in order to simulate field infestations under different scenarios. The first results indicated that a CBB population carrying that *Rdl* gene could maintain CBB populations under the threshold level in the field even when temperature rises above 21 °C. A novel autocidal control strategy of transformed CBB lines will be proposed.

## B 14

PYRAMIDING OF RUST RESISTANCE GENES AS AN APPROACH  
FOR DURABLE RESISTANCE IN ARABICA (*COFFEA ARABICA L.*) -  
INDIAN EXPERIENCE

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Coffee leaf rust (CLR) caused by the obligate parasitic fungus *Hemileia vastatrix* Berk & Br. is the major disease of concern for arabica coffee (*Coffea arabica* L) production, leading to escalation of production costs. Even though, timely sprays of prophylactic and systemic fungicides are effective for disease control, cultivation of tolerant varieties is the most preferred and viable options for economic and environmental sustainability. Hence, rust resistance has been the major focus in Arabica breeding world over leading to the development of several commercial varieties that manifest a wide spectrum of tolerance in field. On the other hand, breakdown in resistance has been observed in the commercial strains on cultivation in large areas due to the evolution of new virulent races of CLR pathogen. This phenomenon is more common in countries like India where the climatic conditions are favourable for rust disease build up. Therefore, development of improved coffee cultivars with long lasting durable resistance in field, is a crucial priority of arabica improvement programmes.

Resistance to coffee leaf rust is reported to be governed by nine resistance genes,  $S_H$ 1 to  $S_H$ 9, either singly or in combination. The corresponding virulence factors in the pathogen are designated as v1 to v9. Of the nine  $S_H$  genes reported so far,  $S_H$ 1,  $S_H$ 2,  $S_H$ 4 and  $S_H$ 5 were identified in the tetraploid *C. arabica* where as  $S_H$ 6,  $S_H$ 7,  $S_H$ 8 and  $S_H$ 9, were introgressed to *C. arabica* from the diploid species *C. canephora*, while  $S_H$ 3 was introgressed from another diploid species *C. liberica*. Considering the durable nature of  $S_H$  genes of diploid origin, pyramiding of resistance genes introgressed from diploid coffee species in a selected arabica genotype is a promising approach to achieve durable rust resistance.

In India, systematic breeding efforts have been undertaken for the last 12 years to pyramid the rust resistance genes of diploid origin in arabica using the *C. canephora* and *C. liberica* introgressed lines. The field performance of the hybrids between Catimor and *C. liberica* introgressed lines with respect to yield potential and resistance manifestation is very promising. Availability of SCAR markers linked to  $S_H$ 3 gene facilitated the marker-assisted selection in these populations. By integrating the SCAR assays and Bioassays, elite plants possessing  $S_H$ 3 besides other genes of arabica ( $S_H$ 2,  $S_H$ 5) and robusta ( $S_H$ 6 to  $S_H$ 9) origin are being identified for commercial exploitation. Encouraged by the positive results, pyramiding of  $S_H$ 3 gene in Sarchimor derivatives has been undertaken recently and new hybrid lines have been evolved. Further, pyramiding of resistance genes present in *C. congensis* in *C. arabica* (Catimor) through triploid *C. Congensis* x R hybrid also found useful in improving the resistance of Catimor.

The present communication highlights some of the leads achieved in India in marker assisted selection for tracking  $S_H$ 3 gene in new breeding lines and in pyramiding of various rust resistance genes in *C. arabica* cultivars as a strategy for durable resistance.

LARGE-ESCALE EXPRESSION OF GENES RELATED TO  
PHYTOALEXINS, PHENOLS, FLAVONOIDS AND LIGNIN  
BIOSYNTHESIS IN COFFEE PLANTS INFESTED WITH LEAF-MINER

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Plants under attack by pathogens usually trigger a complex defense response controlled by specific gene activation, which results in the synthesis and accumulation of secondary metabolites (phytoalexins and phenolic compounds), macromolecules (callose, lignin, glicoproteins) and other proteins. In order to gather information regarding molecular basis of resistance/susceptible responses, expression of genes involved in the biosynthesis of phytoalexins, phenols, flavonoids and lignin was analyzed in coffee plants infested by the leaf-miner. Leaves from both susceptible and resistant genotypes were collected at three different times of infestation: T0, T1 (oviposition) and T2 (egg eclosion). Expression profiles of 184 genes were determined upon data analyses of large-escale microarray hibridizations. These analyses indicated that 27 genes exhibited differential expression between susceptible and resistant genotypes at T0, with foldchange values ranging from 9 to -5. At T1, 27 genes exhibited differential expression with foldchange values ranging from 10 to -10. Finally, differential expression was observed for 34 genes at T2, and foldchanges values range from 60 to -9. Genes involved in phtyoalexins synthesis were also super-expressed at T0 in resistant genotypes, and those related to lignin synthesis were repressed, suggesting that there is no *de novo* synthesis of lignin. At T1, genes directly involved in tanin synthesis were super expressed in resistant genotypes, as opposite to response of susceptible genotypes where chalcone synthase and peroxidase genes are super-expressed. Expression of laccase, peroxidase and leucoanthocyanidin dioxygenase is increased at T2 in resistant plants, and in susceptible plants the increase is observed for phenylalanine ammonia lyase, (PAL), CHS and flavonone dehydrogenase. Differential expression of genes such as laccase, anthocyanidin reductase, and isoflavone reductase, super-expressed in resistant genotypes at T0, indicate that simultaneous synthesis and degradation of tanins may occur at this point, building a barrier against insect nutrition. Also, tannins form complex molecules with lignin and cellulose, protecting them from degradation. Once PAL, CHS and POX are genes involved in the up stream steps of flavonoids, phenylpropanoids, isoflavones and tanin biosynthetic pathways, the observed gene expression profiles suggest that susceptible genotypes exhibited a delayed response to the leaf-miner stimulus. Also, these results suggest that an earlier response is triggered by resistant genotypes, supporting the hypothesis that these plants have a more efficient defense mechanism than susceptible ones.

**A 22**

## RUST RESISTANCE IN ARABICA COFFEE CULTIVARS IN PARANÁ, BRAZIL

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Several cultivars developed by coffee breeding programs in Brazil have presented complete resistance to rust, but with the emergence of new races, these cultivars currently show different levels of resistance. The objective of this research was to evaluate the resistance to rust in coffee cultivars developed by research institutes of Brazil in Paraná state. The experiments were planted in October and November 2006, in Congonhinhas and Londrina, respectively, in the spacing 2.50 x 0.75m, in a randomized block design with three replications and plots of 10 plants. Resistance to the local leaf rust races was assessed in high disease intensity field conditions at Londrina and Congonhinhas in the years 2009 and 2010. The cultivars were developed by EPAMIG/UFV, IAPAR, IAC and MAPA/Procafé. The resistant standard 'IAPAR 59' and the susceptible standard Catuaí Vermelho IAC 144' and 'Bourbon Amarelo' were used. A scale from 1 to 5 based on rust severity was used to evaluate resistance. The data was submitted to analysis of variance and the means were compared by the Scott-Knott test at 5% significance. The cultivars Catiguá MG 1, Catiguá MG 2, IAPAR 59, IPR 98, IPR 104, Palma II, Paraíso H-419-10-6-2-5-1, Paraíso H-419-10-6-2-10-1, Paraíso H-419-10-6-2-12-1, Pau Brasil MG 1 and Sacramento MG 1 presented complete resistance to rust at Londrina and Congonhinhas. Cultivars derived from the Catuaí germplasm were susceptible or showed different levels of partial resistance. 'IPR 103' ("Catuaí") presented a good level of partial resistance in Londrina and Congonhinhas. 'Catuaí Amarelo 2SL' presented partial resistance similar to 'IPR 103' in Congonhinhas. 'Catuaí Vermelho 20/15 cv 476', 'Catuaí Amarelo 20/15 cv 479', 'Catuaí Vermelho 785/15' and 'IPR 100' were statistically equal to the susceptible standard 'Catuaí Vermelho IAC 144' in Congonhinhas. 'Acauã', 'Araponga MG 1', 'Obatã IAC 1669-20' and 'Tupi IAC 1669-33' are normally mentioned as being completely resistant by various authors, but in the present research it was observed partial resistance in these cultivars. It is interesting to note that 'Acauã' and 'Obatã IAC 1669-20' were completely resistant in Londrina statistically equal to the standard IAPAR 59, but were only partially resistant in Congonhinhas. The same occurred for 'Catuaí Amarelo 20/15 cv 479' that was partially resistant in Londrina and susceptible in Congonhinhas. These different resistance reactions are indicating that in Congonhinhas experiment had a new rust race.

A 14

NEW RECORD AND OUTBREAKS OF BACTERIAL BLIGHT OF COFFEE (*PSEUDOMONAS SYRINGAE*) IN SOUTHERN ETHIOPIA: IMPACT OF CLIMATE CHANGE SCENARIOS

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So far, apart from the three calamitous diseases, namely coffee berry disease, coffee wilt and leaf rust, others are unimportant on Arabica coffee (*Coffea arabica* L.) in Ethiopia. There have been, however, sporadically severe outbreaks impacting the crop production. The case in point is bacterial blight of coffee (BBC). Bacterial blight of coffee also known as Elgon or Solai dieback, caused by *Pseudomonas syringae* pv *garcae* van Hall, is reported as a serious disease of Arabica coffee in Kenya, Uganda and Brazil. This bacterial pathogen was earlier noted to associate with branch dieback and bean discoloration of coffee in Ethiopia. In May 2008, outbreaks of uncommon disease of coffee with blight syndrome were observed for the first time in two districts of southern Ethiopia where the famous Sidamo and Yirgacheffe specialty coffees are produced by small-scale farmers. Since then, detailed investigations including diagnostic surveys for assessing the disease occurrence, severity and incidence accompanied by collecting different parts of infected coffee trees in the fields were conducted along with isolation, identification and characterization of the causal pathogen in the Plant Pathology laboratory at Jimma Research Center. The results of three years (2008 – 2011) study showed that the disease syndrome on young, mature and older coffee plants were similar with bacterial blight of coffee documented elsewhere. The disease invariably attacks coffee leaves, branches and shoots with characteristic blight symptoms (photo 1). The infected branches and shoots dieback starting from the point of infection towards the tip while coffee berries on infected branches are also completely destroyed leading to total crop failure. The isolation and identification of the causal pathogen from samples of leaves, berries, branches and shoots consistently produced a bacterial species which belongs to *Pseudomonas syringae* that further proved by characterization and pathogenicity tests (photo 2 & 3). The disease incidence and severity during the first outbreak (2008) was about 90 and 68 percent, respectively. In subsequent years, in addition to increase in the disease progress in already affected areas, fresh BBC outbreaks were discovered on coffee trees in 11 sub-county of the neighboring districts with mean incidence and severity of 95 and 60%, respectively. Besides the sample based survey, comprehensive data analysis indicated significant severity that ranged from 2.3 to 34.7, 6.4 to 38.4 and 2.6 to 45.7 percent in Dara, Aletawondo and Aletachuko respectively, resulting in considerable yield losses. Among others, climatic factors mainly unusual temperature and rainfall (intensity and duration) showed strong correlation with the incidence and severity of the disease outbreaks thereby implicating the present climate change scenarios are upsetting Arabica coffee production in east Africa.



**B 12**

**APPLICATION OF COFFEE RUST GENOMICS TO THE  
UNDERSTANDING OF ITS EVOLUTION**

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Coffee rust, caused by the fungus *Hemileia vastatrix*, leads to widespread damage to crops worldwide. The pathogen has been reported to cause average yield reductions of up to 30% in susceptible varieties of the species *Coffea arabica*, if mild epidemics are not controlled, and complete yield losses under full epidemic developments. We have applied genomics to study population evolution of this pathogen due to a recent outbreak of the disease in Colombia.

A deep DNA and RNA sequencing was carried out in 8 and 3 *H. vastatrix* isolates respectively. According to the results using the software CEGMA, a first estimation of the *H. vastatrix* genome size resulted in over 250Mb, with our sequencing data covering around 92%, that exhibited a GC content of 32%. Additionally, in order to eliminate possible contaminants from coffee tissues or phyllosphere organisms, we analyzed this set of sequences data with the software MEGAN4 finding that all contaminant sequences represented less than 1% of the *H. vastatrix* datasets. Most *H. vastatrix* sequences had a homologous sequence with other fungal sequence or were uncharacterized.

Illumina RNA-seq outputs were assembled with the software Trinity (Grabherr *et al.* 2011) with a total of 44,297, 55,791 and 64,752 contigs obtained for the three sequence datasets. Average contig sizes for the assembled transcriptomes were 675, 716 and 828bp. RNA-seqs from an isolate taken from *Coffea arabica* var. Caturra, presumably *H. vastatrix* race II, map well to the same isolate assembled genome, but isolates taken from other coffee hosts did not map as well to this genome. In the other hand, homology analysis of the transcriptomes from the 3 isolates revealed that they only share 76-78% of their sequences. We concluded that *H. vastatrix* isolate/race diversity at the transcriptome level is significant.

Just 36% to 44% *H. vastatrix* RNA-seqs from the isolates had a homologous sequence with *Puccinia* or *Melampsora* proteins showing the high level of genetic diversity present in rusts. With this level of dissimilarity it is essential to predict *H. vastatrix* proteins by training gene predictor programs with the coffee rust RNA-seq and genome sequences given that other rust protein sequences are not well related to function as models. We have also identified that over 60% of the *H. vastatrix* genome contains putative transposon sequences. Even though the identification of differences in secretomes of several *H. vastatrix* isolates is in progress, we already have identified a set of *H. vastatrix* sequences which are presumably involved in pathogenesis of the fungus.

Molecular markers and aggressiveness tests performed in coffee rust isolates suggested that the recent epidemic of the disease in Colombia was caused by race II or a close genetic variant of this race. Genome sequencing is a powerful tool for the study of *H. vastatrix* mechanisms to infect coffee and to identify genetic differences between races and isolates of the pathogen.

**A 15**

**ARABICA COFFEE PRODUCTION IN THE YUNAN  
PROVINCE OF CHINA**

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Arabica coffee was introduced into Yunnan province of China in 1892 by French missionaries. In 1950s, the coffee growing area at Yunnan was about 4.000 ha of Typica and Bourbon varieties introduced from Burma. Mainly due to coffee leaf rust this decreased to 270 ha in 1970s. In the 1980s and 1990s the Dehong Tropical Agriculture Research Institute of Yunnan (DTARY) released two rust resistant cultivars, respectively S288 introduced from India and Catimor from the Coffee Rust Research Center (CIFC) in Portugal. Because of low yield, poor cup quality and susceptibility to coffee leaf rust (CLR) and stem borer, the cultivar S288 has been gradually replaced by Catimor.

In 2011, the coffee area in Yunnan had expanded to 43.000 ha, with 90% planted to a Catimor cultivar, namely CIFC 7963 (Caturra 19/1 x HDT 832/1). In 2010 the production of green coffee reached 49.400 tons. DTARY recorded in their experimental fields with Catimor yields of 3 to 5.25 tons/ha/year on average, with an occasional top year of 7.5 tons/ha. These yields are obtained at a plant density of 5000–6250/ha, with inputs of fertilizers 2 times/year and of pesticides, 3 times/year, to control stem borers.

According to the production plans of Yunnan Province, the coffee-growing area will increase to 66.700 ha by the end of 2015, with an expected annual output of some 96.000 tons of green coffee. Nowadays, there are more than 200,000 coffee growing households in Yunnan and nearly 700,000 persons benefit directly or indirectly from the coffee industry.

The major coffee regions are located at altitudes between 700 and 1700m and latitudes 21°N (Menghai county, Xishuangbanna District) and about 26°N (Huaping County, Lijiang District). In these regions average temperatures are 18.9-22.4°C, annual rainfall 700-1700mm and 1800-2300 sunshine-hours/year.

The cup quality of Catimor coffees produced in Yunnan reached the international standard of B++ to A++ depending on cultivation altitude. Three coffee bean samples from a Catimor coffee plantation at Lujiangba have also been sent to the SCAA (Specialty Coffee Association of America) for cup testing and received quality scores of 77, 79 and 81.

Unfortunately, over the past few years the cultivar Catimor has become susceptible to leaf rust. Recently, rust races not yet earlier found in China were characterized at CIFC: race VIII ( $v_{2,3,5}$ ) from cultivar S288 and races XXXIII ( $v_{5,7}$  or  $v_{5,7,9}$ ), XXXIV ( $v_{2,5,7}$  or  $v_{2,5,7,9}$ ) and XLII ( $v_{2,5,7,8}$  or  $v_{2,5,7,8,9}$ ) from Catimor. A new rust race with the virulence genotype ( $v_{1,5,7}$  or  $v_{1,5,7,9}$ ) was also detected in Catimor samples. Meanwhile, DTARY and CIFC have started a cooperative programme to introduce new coffee germplasm with broad spectra of resistance to leaf rust and guidelines have been given to prevent or delay the emergence of new rust races.

## B 13

SUSCEPTIBILITY ASSESSMENT OF (COFFEA SPP) COFFEE GENOTYPE TO THE *Mycena citricolor* FUNGUS AND DETERMINATION OF CANDIDATE DEFENSE GENES**ECHEVERRÍA-BEIRUTE, Fabián**

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In Costa Rica, the presence of the *Mycena citricolor* fungus in coffee plantations (*Coffea arabica*) has reduced the yields, and production costs have increased while trying to control the fungus. In this sense, the best control strategy is the incorporation of coffee materials with genetic resistance. To determine the potential of genetic resources of the *Coffea* genus for resistance to this fungus, a study was conducted in 2009-2010. The susceptibility of 33 coffee accessions from nine species of the *Coffea* genus were evaluated in the laboratory using a highly pathogenetic strain of *Mycena citricolor* previously isolated and cultivated *in vitro*. That *in vivo* evaluation was performed in an equipped humid chamber in the Laboratory of Phytopathology of the Center for Coffee Research (CICAFE) in San Pedro de Barva, Heredia, Costa Rica. Once evaluated those genotypes, as part of this study some samples were molecularly analyzed at the Molecular Biology Laboratory of the Agronomic Research Center (CIA), in the University of Costa Rica, San Pedro de Montes de Oca, San José, to determine the presence of potential candidate defense genes in the accessions evaluated. The percentage of leaf area damaged, sporulating lesions and diameter of lesions were calculated in the pathogenicity test at 4, 7 and 10 Days After Inoculation (DAI). The study reported 100 percent of lesions in the *C. arabica* genotypes at 4 DAI, and less than 55 percent in *C. canephora*. Sporulation in new lesions manifested after the 7 DAI, especially in *C. arabica* genotypes. The diameter of lesions at 10 DAI was higher for *C. eugenoides* and lower for *C. canephora*, *C. congensis* and *C. arabica*. No genotype showed resistance to the pathogen, but there was a variable response in the genotypes evaluated for *M. citricolor* inoculation where some showed a lower infection rate. Related to the molecular analysis, 22 DNA samples extracted from accessions with different susceptibility degrees were used and analyzed through PCR with 12 pairs of primers used by other studies for NBS/LRR genes. A variable polymorphism level was obtained between 0 to 67 percent for 9 pairs of primers. No similar bands to those reported in other species were detected, although 16 of the bands could be associated to resistance or susceptibility to the pathogen.

## PA 306

INTROGRESSION OF THE RUST RESISTANCE GENE  $S_H^3$  INTO COLOMBIAN ELITE CATIMORS THROUGH A MARKER ASSISTED SELECTION STRATEGY**HERRERA, Juan Carlos\*, HURTADO, Ifigenia, GONZALES, Laura, CORTINA, Hernando**

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Experience on genetic control of phytopathological fungus in different crops including coffee trees, shows that extensive use (in time and space) of resistant varieties raise the possibilities of emergence of new races more and more virulent. Since liberation of the Colombia variety in 1985 and then the Castillo® variety and its regional components in 2005, progressive occurrence of plants with presence of rust symptoms suggest the generation of new *Hemileia vastatrix* races compatible with resistance genes (R genes) carried by these Catimor derivatives. Introgression into Colombian varieties of a new gene such as  $S_H^3$  would facilitate creation

of genotypes carrying new combinations of R genes which will operate in the field as a genetic barrier against predominant rust races. Recent identification of molecular markers linked to the  $S_h3$  gene issued from *C. liberica* (Mahé et al, 2008; Lashermes et al., 2010) have opened the possibility of real implementation of an strategy of marker assisted selection (MAS) in coffee breeding programs around the world. The aim of this work was to develop advanced lines (i.e. F4) recombining the  $S_h3$  along with the R genes already present in the Colombian elite genotypes and derived from the Timor Hybrid (i.e.  $S_h6$  to  $S_h9$ ). To do that, the Coffee Breeding Program of Cenicafé starts in 2010 a wide cross pollination program involving 44 élite Catimors derived from different accession of the Timor Hybrid (i.e. CIFC-1343, CIFC-832 and CIFC-2252) and some selected Arabica genotypes present in the Colombian gene bank and known as be introgressed by the  $S_h3$  gene. During first part of this project more than 130 crosses have been produced, giving as result almost 500 F1 hybrid plants. Using a MAS strategy, almost 250 F1 seedlings carrying the  $S_h3$  gene have been identified and will be transferred to the field in order to obtain F2 seeds. Once planted, the F2 families will be evaluated and selection for desirable types involving high rust resistance and vigor, elevated productivity and good bean size will be done. The F3 families derived from best F2 plants will finally be evaluated by regional adaptability and high cup quality in order to select the best F3-F4 lines. These genotypes will be used as part of composite varieties which have been the central point of the strategy used by Colombia in order to achieve a more durable resistance by maintaining a high genetic diversity against this disease.

## PA 309

### STRENGTHENING PRODUCER ORGANIZATIONS TO SPEED UP THE MULTIPLICATION OF IMPROVED HYBRID COFFEE VARIETIES IN TANZANIA DEFENSE GENES

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Recent progress in coffee research by the Tanzania Coffee Research Institute (TaCRI) has led to the release of 15 Arabica hybrid coffee varieties that are resistant to coffee berry disease (CBD) and coffee leaf rust (CLR) and 4 Robusta hybrid coffee varieties that are resistant to coffee wilt disease (CWD) that threaten both Arabica and Robusta coffee growers in the country. These improved varieties are the foundation for a coffee green revolution in Tanzania as they are high yielding, resistant to the major pests, have good cup quality and adapted to a wide range of environments. However, since they are hybrids their multiplication is through vegetative propagation. TaCRI has perfected two methods, clonal propagation and grafting for their multiplication, which go together with the provision of training courses to producer organizations to accelerate the multiplication of improved hybrid seedlings. Linkage has been established with over 600 nurseries of the improved hybrid varieties for both Arabica and Robusta coffee varieties scattered across the country which have the capacity of multiplying over 18 million seedlings per year. The decentralization of seedlings multiplication programme as well as participation of various stakeholders in the management of their own nurseries has resulted into increased number of seedlings multiplication for replanting programmes. This paper outlines the progress achieved in hybrid seedlings multiplication.

**Key words:** Producer organizations, Multiplication, Improved hybrids

PA 311

PARTICIPATORY BREEDING ON ARABICA COFFEE TO  
OBTAIN SUPERIOR LOCAL VARIETY IN ORDER TO SUPPORT  
SPECIALTY ORIGIN COFFEE DEVELOPMENT IN INDONESIA**HULUPI, Retno, NUGROHO, Dwi, MAWARDI, Surip and AMAN AL, Maisyir**

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A participatory breeding on Arabica coffee involving farmers and plant breeders to select superior of local variety(s) has been conducted at Gayo highland (Central Aceh, Northern Sumatra) and Kendenan Plateau (Enrekang, South Sulawesi). The aim of applying this method was to find out superior variety(s) of Arabica coffee having appropriate specific traits and adaptable to such location. Moreover it can be expected to accelerate the process of varieties adoption by local farmers. Collaboration between local farmers and coffee breeder in participatory breeding is also an important step to eliminate farmer's worry in adopting new national variety(s) released by the government whether suitable to their local conditions or not. Selection process was usually initiated by the farmer(s) based on high yielding performance by using their native experiences. The next step was conducted by plant breeder in cooperation with coffee farmers and other relevant scientists to evaluate more detail yielding capacity, agronomic traits, resistance to leaf rust and/or parasitic nematode as well as cup quality profile. Cup profile also evaluated by overseas professionals. Yielding ability was observed on its parent-offspring populations for 3 – 4 years. Selected candidate varieties were compared to commercial varieties (S 795 and Typica) at different farmer's sites for several years observations. The results showed as follows: (1) Two selected varieties namely Gayo 1 and Gayo 2 already been released by Minister of Agriculture for commercial planting at Gayo highland. The two varieties perform excellent cup profile with high yielding ability (2 tones/ha) and tolerant to leaf rust disease. (2) Observation over selected local variety at Kendenan Plateau namely Salongge variety performed lower yielding ability (below 1 ton/ha) and less stable yield over years as well as more heterogenous population in it's offspring than that of existing released varieties planted at the same location. (3) Participatory breeding approach in form of collaboration between farmers and coffee breeders is able to accelerate in developing local specific varieties.

Keywords: Participatory breeding, arabica coffee, local variety, coffee specialty.

PB 263

IMPACT OF LONG-TERM INCREASED AMBIENT  
 $\text{CO}_2$  ON COFFEA ARABICA AND C. CANEPHORA  
PHOTOSYNTHETIC FUNCTIONING

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Coffee business involves around 100.000 million USD and employs (directly or indirectly) ca. 500 million people worldwide, based in the trading of *C. arabica* and *C. canephora* beans. In the field plants are often exposed to various environmental stresses that limit plant growth and photosynthesis, and impose changes at cell and whole plant metabolism, namely, of carbon and nitrogen. That is likely to become exacerbated in many regions as a consequence of climate changes. To a certain extent, plants are able to cope with environmental limitations and to maintain an efficient functioning due to a wide range of complementary mechanisms that protect the cell as a whole and the photosynthetic apparatus in particular. In the context of climate changes, this work aim at providing insights concerning the impact of predicted increases of atmospheric  $\text{CO}_2$  on the coffee plant. For that, 1.5 year plants of *C. arabica* cv. Icatu, *C. arabica* cv. Catucá 108 and *C. canephora* cv. Conilon (Clone 153) were transferred into walk-in chambers (EHHF 10000, Aralab, Portugal) and grown under environmental controlled conditions of temperature (25/20 °C, day/night), RH (75%), irradiance (ca. 700 mmol m<sup>-2</sup> s<sup>-1</sup>) and photoperiod (11.5 h), exposed to two defined  $\text{CO}_2$  concentrations  $\text{CO}_2$  (380 or 700 mL L<sup>-1</sup>). After 8 months several parameters (from morphological up to gene expression) were evaluated in the leaves developed entirely under these conditions. The first results pointed to growth (height and leaf area) increases under high  $\text{CO}_2$  conditions. Although membrane permeability did not suffer appreciable modifications with elevated  $\text{CO}_2$ , changes occurred in the photosynthetic apparatus functioning. The net photosynthetic rate remained higher at 700 than at 380 mL L<sup>-1</sup>, both in the morning and afternoon periods, with similar (Clone 153, Icatu) or higher (IPR108) stomatal conductance (thus, with implications on water use efficiency). Furthermore, the plants grown at 700 mL L<sup>-1</sup> showed higher photosynthetic capacity (measured at 25 °C and saturating light and  $\text{CO}_2$ ) and saturated at higher irradiance. That could be related to the somewhat increased electron transport rates at photosystems I and II level (when expressed in a chlorophyll basis), although a fluorescence analysis did not depicted obvious differences amongst  $\text{CO}_2$  treatments in the three genotypes. These studies are under course and the results will be discussed considering a wide physiological, biochemical and molecular analysis, allowing an integrated view of the photosynthetic apparatus functioning in response to new environmental  $\text{CO}_2$  availability.

**A 16**

**LESSONS FROM CAFNET: AN INTERNATIONAL PROJECT DOCUMENTING ENVIRONMENTAL SERVICES OF COFFEE AGROFORESTRY IN CENTRAL AMERICA, INDIA AND EAST AFRICA.**

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For 5 years (2007-2011), the CAFNET project (Connecting, enhancing and sustaining environmental services and market values of coffee agroforestry in Central America, East Africa and India) was financed by the Union European with the objective of linking sustainable management and environmental benefits of coffee agroforestry systems with appropriate remuneration for producers through better access to markets and payment for environmental services.

This presentation will highlight some of the main scientific results documenting environmental services provided by coffee agroforestry systems in 7 countries (Costa Rica, Guatemala, Nicaragua, Uganda, Kenya, Rwanda and India), particularly in terms of soil fertility, coffee quality, biodiversity conservation, water yield and carbon sequestration.

This presentation will also describe how the CAFNET team has contributed to help farmers' organizations on these 3 continents: 1) to enhance their access to information on markets and eco-labels, and 2) to improve their capacity to propose locally-adapted changes to certification criteria of eco-labels promoted by NGO and the private sector.

This presentation will also illustrate how CAFNET has been able to increase awareness locally and internationally on the important role of coffee agroforestry systems in terms of provision of environmental services.

Finally, this presentation will highlight some of the policy recommendations made by CAFNET to governmental institutions to change forest rules or regulations in order to promote coffee agroforestry practices, and to develop or improve pilot schemes for payment of environmental services to coffee communities.

**A 17**

**IMPROVING WATER PRODUCTIVITY IN ARABICA COFFEE**  
(minireview)

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Water productivity (WP) is defined as the yield per unit of water used by the developing crop (evapotranspiration). In the face of aggravating global freshwater scarcity, due to climate change and human factors, there is an urgent call to increase agricultural productivity per unit of water or “more crop per drop”. It is a serious question that requires a combination of crop physiological, genetic/genomic and agronomic approaches.

Drought-tolerance in coffee is usually associated with early stomatal closure in response to water stress, but that reduces CO<sub>2</sub> assimilation and consequently lowers yield. Recent molecular-genetic research projects, mainly on young coffee plants in growth chambers, have identified genes that control responses to dehydration stress, but their effects on yield are still unknown. It seems unlikely that this approach will make a substantial contribution to breeding for improved WP of arabica coffee, at least in the short term.

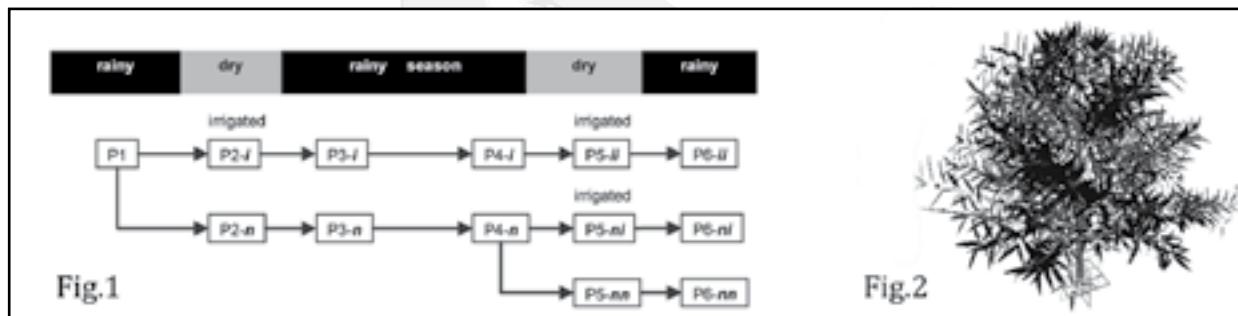
Recently developed Australian sorghum cultivars with the “stay-green” leaf trait have yielded significantly more under drought stress than those without this character. The delayed leaf senescence allows for longer uptake of soil water and plant nutrients, therefore uninterrupted photosynthesis and more carbohydrates becoming available for grain filling. A similar physiological mechanism appears to operate in the increased leaf retention and enhanced greening of arabica coffee induced by “tonic” sprays of broad-spectrum fungicides. In Kenya, this resulted in yield increases of 40-85%, cumulatively over five years, for coffee genotypes resistant to coffee berry and leaf rust diseases. There were highly significant varietal differences in leaf retention responses to stress conditions, independent of tonic sprays. It is evident that selection for leaf longevity plus tonic sprays of fungicide (on disease resistant cultivars only) can significantly increase water WP in arabica coffee.

Other strategies for increasing WP of arabica coffee include: (1) high-density planting: complete ground cover results in less soil water lost by evaporation and transpiration from weeds, deeper root system leading to more efficient uptake of water and plant nutrients; (2) short-stature cultivars (Ct-gene): these transpire some 25% less water than *typica* or *bourbon* coffee cultivars with more open crown architecture; (3) shade trees in areas marginal to coffee cultivation (adverse climatic and/or edaphic conditions): to reduce soil and atmospheric water deficits, temperature extremes and wind speed; (4) adequate supply of plant nutrients: leaf longevity and photosynthetic capacity are related to leaf-nutrient status, N in particular.

**A 18**
**MODELLING VEGETATIVE GROWTH AND ARCHITECTURE  
OF COFFEA ARABICA CULTIVARS UNDER WATER STRESS**
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Two *Coffea arabica* cultivars, IAPAR59 (drought tolerant) and RUBI (drought susceptible), were grown for two years with/without irrigation during the dry season\*. In addition of eco-physiological, anatomical and molecular biology observations, complete descriptions of plant architecture were performed. All architectural data were analyzed owing to the AMAPstudio-XPlo software. The methodology for analyzing data and the main results are presented here.

**Material and methods:** 17 plots including 39 plants of each cultivar were set in the experimental station of Embrapa-CPAC, Brazil (15°35' S, 45°43' W). Three irrigation treatments were applied as shown in fig. 1 with "i" and "n" coding irrigated and non-irrigated plots respectively. Three times a year (before, during and after the dry season) 7 to 21 plants of each cultivar were collected for architectural descriptions, leaf area and dry mass measurements. Architectural data were coded in the MultiscaleTreeGraph (MTG) format and loaded in the AMAPstudio-XPlo software for visual checking (fig. 2) and data extraction in an interactive mode or by scripting. Data were exported to R for further analyses.



**Results:** When irrigated, the two cultivars had a comparable vegetative development except for the number of secondary branches (higher for Rubi) and the size of leaves (smaller for Rubi, resulting in lower LAI). The first dry season decreased the number of trunk nodes and the number of primary branches. Delayed effects were still observed in P4, especially for RUBI. The (more severe) water stress on the second year increased the phyllochron for both cultivars and inhibited the setting up of new secondary and tertiary branches. This latter effect was proportionally much higher for Rubi. Plants irrigated only on the second year recovered only partially from the 1<sup>st</sup> year stress. A specific response of Rubi to irrigation was the setting of numerous secondary branches in P5-ni and P6-ni.

**Discussions and perspectives:** Structuring biometric variables according to the plant architectural organization (MTG) is a fruitful method for addressing plant traits such as the plant plasticity to drought. It also provides matchless information for building Functional Structural Models accounting for biomass allocation and plant strategy

\* see Rodriguez *et al.* poster in ASIC 2010

A 19

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**AN ASSESSMENT OF THE CONTRIBUTION OF THE COFFEE GROWING REGION OF COLOMBIA TO THE CONSERVATION OF BIRDS OF CONSERVATION CONCERN**

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A variety of empirical studies have documented the occurrence of birds of conservation concern, both threatened or endemic, in the coffee growing region of Colombia (CGR). However it is unclear to what extent the coffee growing region is important for birds of conservation concern in the country and what management actions within this agroecosystem could help to achieve the nationwide conservation goals for birds.

In this study, we used species distribution modeling as a tool to estimate to what extent 113 bird species of conservation concern may potentially occur in the CGR. We also used field data to determine whether these birds were directly associated to coffee plantations or natural vegetation remnants in this region. Finally, to determine the contribution of the CGR to conservation of birds in the country, we conducted a nationwide conservation gap analysis, for which we selected a representation target of 2000 km<sup>2</sup>, meaning that a species was considered as represented in the protected areas network if at least 2000 km<sup>2</sup> of its distribution fell within it.

Distribution models predict the presence of 74 bird species in the CGR, which represents an increase of 50 species over the number of species currently recorded. Additionally, we identified 13 species of conservation concern that are strongly associated with coffee plantations, 53% of which occurred exclusively in shade-grown coffee plantations. Our gap analysis revealed that representation targets for nine species could be met by conservation actions directed to existing natural vegetation remnants in the CGR. In addition, three species could meet their representation target if coffee plantations within their range were transitioned from sun to shade. This research highlights the importance of the CGR for the conservation of birds in the country and suggest management actions to achieve national targets of conservation of bird species'.

## A 20

## SHADE HAS ANTAGONISTIC EFFECTS ON COFFEE BERRY BORER

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Shade effects on coffee berry borer (*Hypothenemus hampei*; Coleoptera: Curculionidae) are controversial, possibly because shade affects the pest by stimulating simultaneously different pathways which have opposite effects. The balance of these effects is therefore unsure. The objective of this study was to clarify the effects of shade on *H. hampei*. The research was carried out in 2010, in Turrialba, Costa Rica, at 600 m of elevation, in a trial established by CATIE where different shade trees and coffee managements are compared. We studied several combinations of three levels of exposure to light (full sun, medium shade of *Erythrina poeppigiana*, dense shade of *E. poeppigiana* and *Abarema idiopoda*) and three coffee managements (organic with applications of the entomopathogen fungus *Beauveria bassiana*, conventional with insecticide sprays, and conventional insecticide-free). The response variables were: (i) populations of *H. hampei* in green, ripe and dry berries, (ii) number of bored berries (iii) and berry growth dynamic over time. We also monitored the microclimate in full sun exposure and dense shade conditions.

Shade increased *H. hampei* populations into coffee berries. For instance, with the conventional management with insecticides, we found an average of  $1.9 \pm 0.3$  females per bored ripe berry under dense shade and only  $1.2 \pm 0.2$  at full sun exposure. Similarly, with the conventional management with no chemical control, we found  $11.1 \pm 1.6$  females in bored dry berries, under medium shade, and only  $4.1 \pm 1.6$  females at full sun exposure. This can be explained by the microclimatic conditions which were more favorable to the insect under shade. Under dense shade, temperatures were buffered (particularly high temperatures) and relative humidity and plant organs wetness were higher as compared to full sun exposure. In addition, we observed an earlier berry ripening at full sun exposure compared with dense shade. In July-August, at full sun exposure, 11 % of the berries suitable to the pest were ripening berries, while only 3 % under dense shade. These ripening berries were proportionally more attacked than green berries, as 29% of the bored berries at full sun exposure were ripening berries, and 9% under dense shade. Despite this early onset of ripening berries at full sun exposure and their attractant power, we found proportionally more ripening berries infested under shade as compared to full sun exposure, in conventional managements: 58.9% with dense shade and only 5.2% at full sun exposure, when insecticides were applied; 32.9% under medium shade and only 9.8% at full sun exposure with no chemical control. However, this trend was reversed when *B. bassiana* was applied: we found 18.2 % of ripening berries infested under medium shade and only 5.7% under dense shade. The results indicate that shade has antagonistic effects on *H. hampei*. In one side, shade increases coffee berry borer populations when no *B. bassiana* is applied, but in the other side, it decreases the number of bored berries when the entomopathogen fungus is sprayed. These effects are probably due to the microclimatic conditions found under shade which are better for both the coffee berry borer and its natural enemy *B. bassiana*.

A 21

## SHADE IS CONDUCIVE TO COFFEE RUST AS COMPARED TO FULL SUN EXPOSURE UNDER STANDARDIZED FRUIT LOAD CONDITIONS IN A SUB-OPTIMAL ZONE FOR COFFEE IN COSTA RICA

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Shade effects on coffee rust are controversial, possibly because shade helps to prevent high fruit loads, which decreases leaf receptivity to the pathogen but, at the same time, might provide a better microclimate for germination and colonization. These two probable antagonistic pathways are combined under natural conditions.

In order to clarify their individual effects, we dissociated the two factors by manually homogenising fruit loads under two light exposure situations, under shade and in full sunlight.

The trial was set up in Turrialba, Costa Rica at 600 m of elevation, in a coffee plot initially under shade provided by the tree legume *Erythrina poeppigiana*. The plot was subdivided into two subplots: one was maintained under shade, whereas shade was eliminated in the second subplot. In each subplot, we removed fruiting nodes from 40 coffee plants in order to obtain the following four levels: none, 150, 250, and 500 fruiting nodes per coffee plant. Coffee rust incidence and severity, along with plant growth and defoliation, were assessed on these coffee plants over a period of two years. Air and leaf temperatures, leaf wetness and relative humidity were also monitored.

As expected, the intensity of the coffee rust epidemic increased in line with fruit load. We quantified a 28.9% increase in coffee rust incidence and a 129.2% increase in severity on plants with 500 fruiting nodes as compared to plants with no fruits. With the homogenised fruit load, the intensity of the coffee rust epidemic was greater in the shaded subplot, with a 21.5% increase in incidence and a 22.4% increase in severity. Two mechanisms were suggested. Firstly, we highlighted a dilution effect due to host growth which was 25.2% and 37.5% greater in full sunlight when considering new leaves or new leaf area respectively. Secondly, the microclimate was more conducive to coffee rust under shade, with lower intra-day temperature variations, due to lower maxima, and a higher leaf wetness frequency.

We concluded that shade has antagonistic effects on coffee rust. Coffee rust is reduced by shade because shade reduces the number of fruiting nodes and the number of fruits per node. However, with an equivalent number of fruiting nodes, coffee rust incidence and, to a lesser extent, severity were greater under shade. The service provided by shade in controlling coffee rust is necessarily associated with a disservice that consists in reducing yield in the short term.

**A 10****SUCCESSFUL CASE STUDIES OF ADOPTING IMPROVED COFFEE VARIETIES IN TANZANIA****KILAMBO, Deusdedit\*, MTENGA, Damian\*, NG'HOMA, Nyabisi\*, NGOMUO, Robert\* and TERI, James\****\*Tanzania Coffee Research Institute (TaCRI), P. O. BOX 3004, Moshi, Tanzania*

Fungal pathogens; *Colletotrichum kahawae*, *Hemileia vastatrix* and *Giberella xylosporus* existing in coffee growing areas have been persistently causing economic losses to coffee growers in Tanzania. Through infection of green expanding coffee berries *C. kahawae* can cause losses of between 30-60%, infection of leaves by *H. vastatrix* about 60% and of coffee bushes by *G. xylosporus* up to 100%. IPM control measures have been focused on use of chemical protection, cultural measures, eradication, and exclusion. But importation of fungicides to control fungal pathogens for coffee is costing approximately US \$ 492,000,000 per year. Cultural and eradication measures are cumbersome, and exclusion is in most cases not reliable. Recently, TaCRI recommended 15 improved Arabica hybrids which are resistant to strains of *C. kahawae* and *H. vastatrix*, and four (4) Robusta varieties resistant to infections by *G. xylosporus*. These improved varieties are also of high yielding and excellent beverage quality. Observations made since their establishment on – farm for more than eight (8) years shows potential of these varieties in terms of disease resistance. Three case studies are being highlighted - two for Arabica on – farms, and one in Robusta coffee areas in Western Tanzania. Records of disease resistance for Arabica varieties considered using a rating scale of 1-6; 1, implies resistant and 6, susceptibility. For Robusta varieties scale 1 and 2; 1, resistant and 2, dead. Weather pattern influencing the epidemic of the disease for these locations is part of the study. Varieties under on – farm involves; Arabica hybrids N39-3 (SC8) and KP423-1 (SC10), and Maruku 1 (MR10) and Maruku2 (13/61) for Robusta. One compact breeding line in pipe line for official release was part of the evaluation. Commercial varieties N39 and KP423 for Arabica and MS1 for Robusta were used as checks. Improved coffee varieties continued to portray disease resistance, yield advantage of > than 2 tons per hectare over traditional disease susceptible varieties, and outstanding cup taste described as of specialty coffee. This sows strength of adopting improved coffee varieties over traditional varieties.

**Key words:** Improved, Coffee varieties, Tanzania

A 13

RESISTANCE TO LEAF MINER IN COFFEES CARRYING  
*Coffea racemosa* GENES DERIVED FROM BACKCROSSES  
WITH *Coffea arabica* GENOTYPES

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The coffee leaf miner (*Leucoptera coffeella*) is the main pest on coffee crops in Brazil. All *Coffea arabica* varieties cultivated in Brazil are susceptible to this insect. Chemical control increases production costs and causes environmental pollution. The use of resistant cultivars seems to be the ideal control method. The highest level of resistance is found in *C. stenophylla*. Other species such as *C. liberica*, *C. eugeniooides*, *C. kapakata*, *C. racemosa* and *C. salvatrix* are also considered to be resistant to leaf miner. Resistant cultivars are currently being developed in Brazil using genes from the *C. racemosa* species. The resistance to *L. coffeella* derived from *C. racemosa* can be explained by two complementary dominant genes (*Lm1*, *Lm2*). The aim of this research was to identify resistance to leaf miner in coffees carrying *C. racemosa* genes derived from backcrosses with coffee genotypes. The field assay was established in September 2007 at IAPAR (Londrina, PR, Brazil), using the spacing 2.5 x 0.5m. The experimental design was randomized blocks with three replications, plots with five plants and twenty three treatments. Fourteen coffee genotypes carrying *C. racemosa* genes were evaluated. The F<sub>1</sub> hybrid 'Tupi IAC 1669-33' x [(*C. arabica* x *C. racemosa*) x 'Tupi IAC 1669-33'] was the resistant source to leaf miner used in hybridisations. This F1 hybrid had two cross generations with fourteen coffee genotypes: 'IAPAR 59' ("Sarchimor"), 'Tupi IAC 1669-33' ("Sarchimor"), 'Icatu IAC-3282', 'Catuaí Vermelho IAC-81', 'Acaíá IAC 474-7', 'IPR 98' ("Sarchimor"), 'IPR 104' ("Sarchimor"), 'IPR 107' ("Sarchimor" x "Mundo Novo"), 'IPR 108' ("Sarchimor" x "Catuaí"), "Pacamara", F2 of 'IAPAR 59' x "Catuaí Erecta", "*C. arabica* from Ethiopia carrying S<sub>H</sub>1 gene x Catuaí", "Super Precoce Tp" and "Super Precoce I98". Some of these genotypes are in more than one treatment. These coffee genotypes used in backcrosses were mother plants and the pollinators were resistant to leaf miner. Such as standards for susceptibility to leaf miner the cultivars IAPAR 59 and IPR 99 were used, both of Sarchimor germplasm. The leaf miner severity was evaluated in June 2010 using scores from 1 to 5. Plants with scores 1 and 2 of leaf miner severity were considered resists and with scores 3, 4 and 5 as susceptible ones. It was estimated the percentage of resistant plants of each genotype. The statistical program Genes was used for the analysis of variance at the level of mean of the plots. The Scott-Knott test at 1% was used to compare the means. The standards IAPAR 59 and IPR 99 presented 100 % of plants with susceptibility to leaf miner. The expected frequencies of resistant plants were around 25% or 50%. It should be 25% if the resistant plant used in cross had genotype *Lm1lmlm1 Lm2lm2* and would be 50% to genotypes *Lm1lmlm1 Lm2lm2* or *Lm1lmlm1 Lm2Lm2*. The observed frequencies of plants with resistance to leaf miner varying from 13.33% to 66.67%, indicating that the resistant plants used such as pollinators in the crosses were in heterozygous condition. Fourteen treatments presented around 50% of resistant plants and seven treatments presented around 25% of resistant plants. Resistant plants of each genotype will have a new backcross generation to incorporate genes of these coffee genotypes.

**A 23**

**A CURRENT PERSPECTIVE ON CLIMATE VARIATIONS AND THEIR EFFECTS ON COFFEE DISEASE MANAGEMENT IN COLOMBIA**

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During the 2008 to 2011 growing seasons, an unusual incidence raise of several coffee diseases was recorded around Colombian coffee fields, that comprised uncommon Coffee Leaf Rust (CLR) epidemics above 1,600 m, outbreaks of Pink disease and *Phoma* Die Back, and numerous reports of American Leaf Disease occurring in plantations under full sun exposure. Differences in environmental and agronomic conditions during the period 2008-2011 were considered as direct causes of these diseases high incidence, including deficient fertilizations due to international oil price increases, but mostly the larger and more frequent rainfalls resulting from recurring La Niña events in that period. In the Colombian central coffee-growing region, annual precipitation exceeded in 600 mm the historical average of 2,400 mm. A similar pattern was observed in most of the climatic stations located all over the coffee growing areas where also solar irradiation was on average 11% below the regular 1,775 hours per year. Together with sunlight reductions due to cloudy skies, a narrower range between maximum and minimum daily temperatures, a deficient nutrient uptake in water-saturated soils that slowed shoot growth, preventing plant recovery, and the absence of dry periods, completed the conditions that favoured blooming of pathogen populations. Molecular and phenotypic characterizations of thirty coffee rust isolates taken before and during the current epidemics indicated that the CLR outbreak was caused by isolates belonging to race II, the prevalent race of *Hemileia vastatrix* in Colombia since 1983, with no evidence of increments in race aggressiveness. During the last four years, field experiments of chemical control demonstrated de efficiency of cyproconazol at concentrations of 250 cc/Ha, applied in a preventive and opportune fashion according to the flowering periods and the onset of the rainy seasons, demonstrating the absence of fungicide resistance among *H. vastatrix* field inocula. In addition, a sales records survey of fungicides used in the control CLR indicated that less than 10% of the areas planted with susceptible varieties did receive any degree of chemical protection. Our experimental results and observations corroborated the strong influence of climatic conditions in the widespread activity of CLR and other diseases, and oriented the decision making process for a national campaign to control the disease, that ultimately decreased average incidence levels from 40% to 12%. Field trips and evaluations inside high CLR incidence zones confirmed the durable resistance of multi-line cultivars Colombia and Castillo derived from crosses between Caturra and Timor Hybrid 1343. Towards the future, proper planting densities, weed management, shadowing practices and fertilization schedules should be carefully observed in order to limit the impact of diseases during high precipitation periods. In the long term, the replacement of susceptible varieties for resistant ones is the most economical and environmentally effective measure to be taken. The combined use of historical meteorological data, weather recording stations, field disease evaluations, and epidemiological analysis are now the basis for the implementation of an early warning system, essential for the design of mitigation and adaptation strategies that ensure coffee production in the potential events of climate change in the years to come.

**A 9**

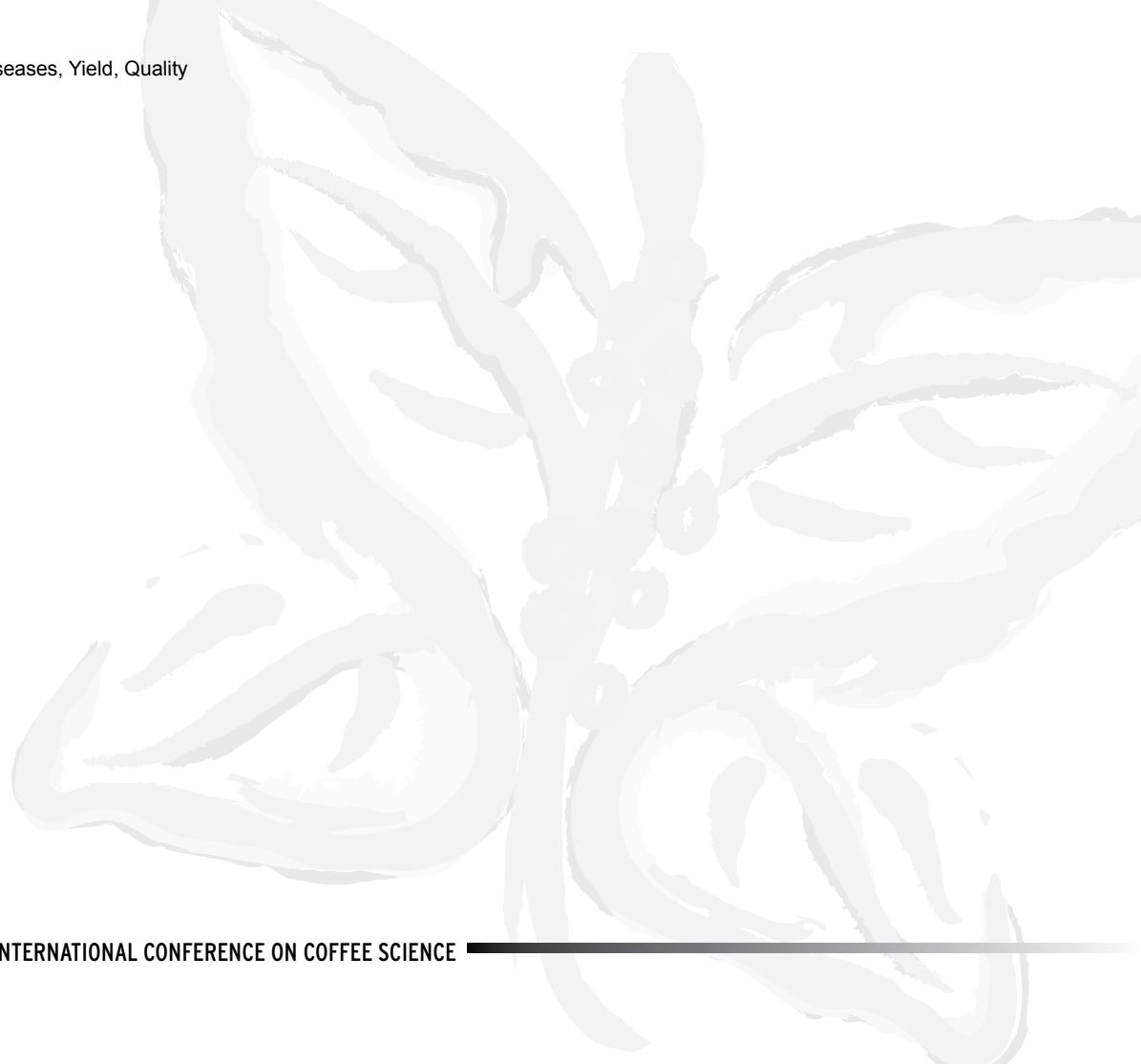
**COFFEE BREEDING IN KENYA: ACHIEVEMENTS, CHALLENGES  
AND CURRENT FOCUS**

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Coffee production in Kenya is seriously constrained by two fungal diseases namely Coffee Berry Disease (CBD) caused by *Colletotrichum kahawae* (Waller & Bridge) and Coffee Leaf Rust (CLR) caused by *Hemileia vastatrix* (Berk. and Br.). Growing resistant varieties is believed to be the most cost effective and sustainable means of managing plant diseases. It has also been recognized that better knowledge of both, the pathogen and the plant defense mechanisms allows for the development of novel approaches to enhance the durability of resistance. On the other hand, consumer awareness about the quality of different coffees has increased steadily in recent years and production and supply of coffee with excellent quality seems more crucial than before for coffee exporting countries. In Kenya considerable success has been made in coffee breeding to improve yields, quality and to manage the two economically important diseases. However, emerging issues such as climate change have brought up new challenges which require to be addressed to ensure sustainability in coffee production. This paper reviews some of the achievements, challenges faced and future prospects/approaches to develop cost effective and sustainable coffee varieties that enhance yield and quality.

**Key words:** Coffee Breeding, Diseases, Yield, Quality







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## POSTER SESSIONS

**Monday, November 12, 2012**

**Chemistry-Physiology-Processing**



**PC400**

**A NEW APPROACH FOR THE PREDICTION OF CAFFEINE CONTENT  
IN RAW COFFEE BY NEAR INFRARED SPECTROSCOPY**

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Currently, the rapid growth of automation and technology has brought modern analytical methods for identification and quantification of the main compounds present in coffee beans and other agronomical products. Among them, HPLC, GC, NMR H1 and electrochemical methods represent the most important technologies. Unfortunately, most of these techniques have disadvantages like a need for complex samples treatments (clean up), moreover they are often time consuming, costly and destructive. To overcome these limitations, attention has been paid to the development of spectroscopic analysis coupled with chemometric tools.

However, to determine the content of a chemical compound present in coffee beans by spectroscopy, the relationship between the information of both, infrared spectra and reference methods, e.g. HPLC, must be established [1].

In this work, 9 green coffee varieties from the IAC germoplasm bank were analyzed using diffuse reflectance near infrared spectroscopy (NIRS) and HPLC in order to determine their caffeine contents. The samples from C. arabica and C. canephora species were selected based on the different contents of this methylxanthine that ranged from 0.07 to 3.52%. One artificial coffee "matrix" with 0.4% of caffeine was obtained by extracting caffeine from a coffee sample with methanol/water (70/30). This matrix was considered as a "variety".

All the 363 Near Infrared spectra were obtained by the mixture of proportions of different species and varieties and also through the addition of pure caffeine. Each spectrum was profiled with 256 scans from 1100 up to 2500 nm at 2 nm resolution respectively. All analyses were made in triplicate.

The aim of this work was the construction and validation of a universal multivariate model to predict caffeine contents in raw coffees using near infrared diffuse reflectance. In this work, the improvement of the methodology was provided by the use of different coffee species and artificial matrices. This approach allowed improving the range of caffeine content in the bean and a reduction of the number of analyses by the reference method. The regions of the spectrum defined as important for the prediction of the caffeine content (selected variables) were visually selected comparing the spectra of the samples with the spectra of the pure caffeine. From the initial 700 variables (NIR spectrum), 81 were selected to represent the caffeine prediction model.

Four latent variables were used for the PLS model. The values of the statistical parameters RMSECV (root mean square error of cross-validation), rcv (correlation coefficient of cross validation) and RMSEP (root mean square error of prediction) were  $0.141 \pm 0.01$ ,  $0.99 \pm 0.00$  and  $0.097$ , respectively. The multivariate regression model for the determination of caffeine was built, tested and validated with 39 external samples.

## PC401

## EFFECT OF MILK ON SENSORY PROFILE AND CONSUMER PREFERENCE OF TURKISH-STYLE COFFEE

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The effect of milk on sensory attributes was determined using sensory mapping and consumer preference studies of selected products from several categories (e.g., economy, main, premium & super-premium). Sensory mapping was performed by an expert panel of coffee tasters while consumer preference survey was conducted at the respective market by a professional company that specializes in this area. Standard statistical methods were used for data analysis. The sensory data in combination with the information provided by consumers were used to determine the affect of milk addition on sensory attributes as well as consumers' response to these changes. Thus, we found major reduction in green and metallic notes while some reduction in acidity, astringency, bitterness and off odor. We also found a decrease in aromatic intensity. Consumer testing data reveals that the impact of milk addition on consumer's likings varies from product to product based on composition and degree of roasting. We also found that the change in consumer liking relates, in part, to the degree of reduction in acidity, astringency, green and burnt notes. A new product that meets consumer's preference was developed based on these findings.

## PC402

## CHARACTERIZATION OF COFFEE GROUNDS FROM ESPRESSO CAPSULES

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Since 2000, when it was released on the market, the consumption of espresso coffee capsules has already exceeded 20 billion units, with a 30% increase per year and handles about 17 billion dollars per year only in the Europe. This increase in consumption has as a consequence the generation of large amounts of residue, making it necessary to study methods that add value to this residue providing opportunities for reuse of the same. This study evaluated the moisture, organic matter content, mineral content, oil content and protein content and calorific value of the residue from the beverage extraction of espresso capsules of four different origins. The average moisture content was high ( $63.6 \pm 1.42\%$  m/m), undesirable factor because energy must be expended in the drying process and also because it makes the material susceptible to microbiological attack, increase the volume for transport e decrease the calorific value. The average content of organic matter was high ( $35.9 \pm 1.75\%$  w/w, DW), desirable factor since this residue may have potential to be used in power generation by combustion, as organic fertilizer or microbial substrate. The average mineral content was low ( $0.61 \pm 0.35\%$  w/w, DW). The calorific value was 20.6 MJ/kg. The average oil content was high ( $10.1 \pm 0.311\%$  m/m, DW), thus the material can be designed for the production of biodiesel by transesterification reactions. The average protein content was high ( $10.4 \pm 0.646\%$  w/w, DW), very important property which shows that this residue has important nutritional properties and may be destined for nobler purposes as a component of animal feed.

PC403

## COMPOSITION AND ANTIOXIDANT ACTIVITY OF ROASTED ARABICA COFFEE FROM DIFFERENT CULTIVARS GROWING IN THE SAME EDAPHO-CLIMATIC CONDITIONS

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Coffee beans composition is affected by genetic characteristics, edapho-climatic conditions, post-harvest and roasting process and the final preparation of coffee brews. Hydrosoluble (nicotinic and chlorogenic acids, trigonelline and caffeine) and liposoluble (cafestol and kahweol) compounds and melanoidins stand out for their contribution to health mainly as antioxidants. The objective of the work was to study the composition and the antioxidant activity (AA) of roasted coffees of traditional cultivars (Catuaí and Icatu) and artificial crosses. The edapho-climatic conditions and roasting process were standardized, so the differences in composition and AA could be mainly attributed to the genetic characteristics of each cultivar. Hydrosoluble and liposoluble compounds were analysed by RP-HPLC and melanoidins by spectrophotometry. Inhibition of linoleic acid autoxidation (formation of conjugated dienes), radical scavenging activity by ABTS (TEAC) and total phenolics (TP) were determined to estimate the antioxidant activity (AA). Principal Components Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were applied to data. PC1 (33% of the variance) was positively correlated to kahweol, melanoidins, TEAC and dienes values, and negatively correlated to cafestol and trigonelline contents. PC2 (22%) was negatively correlated to 5-CQA and TP and positively correlated to nicotinic acid and caffeine. HCA indicated three main groups of coffee varieties. Traditional cultivars showed high levels of cafestol, 5-CQA, trigonelline and caffeine and lower contents of kahweol and melanoidins, nicotinic acid and AA. IPR100, 101 and 105 (Catuaí Sh<sub>2</sub>, Sh<sub>3</sub> genetic background–GB) and IPR106 (Catuaí-GB) showed high levels of nicotinic acid, caffeine, melanoidins and AA (Dienes). Cultivars Sarchimor derived (IPR97, 104 and 107), IPR102 (IcatuXCatuaí) and IPR108 (SarchimorXicatuCatuaí) were discriminated by the high levels of 5-CQA, trigonelline, kahweol, and high AA (TP and TEAC). In general coffees originated by artificial crosses showed higher AA compare to traditional cultivars.

**PC404**

**GREEN COFFEE BEANS COMPOSITION, ROASTED COFFEE  
AND BEVERAGES CHARACTERISTICS: DIVERSITY BETWEEN  
ARABICA CULTIVARS**

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Several genetic crosses result in different green beans composition which coupled with cultural practices, climatic and post-harvest conditions contribute to define the roasted coffee and beverages characteristics. The relationship between the composition of green beans and the characteristics of roasted beans and coffee brews for traditional cultivars (Bourbon, Catuaí and Icatu) and artificial crosses (Iapar 59, IPRs 97, 98, 99, 100, 101, 102 103, 104, 105, 106, 107 and 108) were studied. All coffees grown in the same edapho-climatic condition and had standardized processing conditions. Contents of cafestol, kahweol, trigonelline, 5-CQA, caffeine, total phenolics (TP), sugars (total and reducing), proteins and lipids and density (DensG) were determined in green beans. Density (DensR) and expansion were measured in roasted beans. Titratable acidity and pH were determined in the coffee brews. Principal Components Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were applied to data. Catuaí, IPRs 100, 101, 103, 105 and 106 (Catuaí x Icatu or Catuaí Sh<sub>2</sub>Sh<sub>3</sub>) were discriminated from other (Sarchimor crosses, Bourbon and Icatu) by the high values for nitrogen compounds (trigonelline and caffeine), expansion and pH and lower values of 5-CQA, TP, lipids, reducing and total sugar, DensG (compounds related to maturation) and DensR (PC1, 30% of variance). Catuaí, Icatu and Bourbon and IPR 98 were discriminated by of lower kahweol and higher cafestol values (PC2, 18%). Therefore, some crosses had features in common with the traditional cultivars of which originated them in the green, roasted beans and brews characteristics. The differences between traditional and breeding cultivars were mainly due to the diterpenes suggesting the importance of genetic effect on these compounds content.

## PC405

## DIVERSITY BETWEEN COFFEA ARABICA CULTIVARS: ORGANIC ACIDS COMPOSITION

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The content of organic acids in coffees is affected by factors such as variety and local of growing of coffees, roasting process (temperature and time), brewing process, storage time of the coffee beverage affect. Quinic, malic, citric, acetic, lactic and chlorogenic (5-ACQ) acids were the most important compounds of this class in green and roasted coffees. The content of organic acids for traditional cultivars (Bourbon, Catuaí and Icatu) and modern crosses (Iapar 59, IPRs 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107 and 108) were studied in order to correlate the acids profile and the genetic background of coffees. All coffees grown in the same edapho-climatic conditions and processing operations were standardized. Green beans, roasted coffees and coffee brews were evaluated; the organic acids were quantified by RP-HPLC. The green beans cultivars from a cross of Catuaí Sh<sub>2</sub>Sh<sub>3</sub> (IPRs 100, 101 and 105), IPR 102 (Catuaí x Icatu), 106 (Icatu), 107 (SarchimorxMN) and traditional cultivars were separated from Sarchimor crosses and IPR 103 (characterized by high contents of quinic and citric acids and lower of 5-CQA). Catuaí Sh<sub>2</sub>Sh<sub>3</sub> (IPR 100, 101, 105, 103), IPR 106, Sarchimor (IPR 98, 99 and Iapar 59) and Catuaí were discriminated by the high content of quinic acid and pH observed in roasted coffee and coffee brews. Others cultivars presented high levels of malic, 5-CQA, lactic, citric and high titratable acidity. Cultivars Catuaí Sh<sub>2</sub>Sh<sub>3</sub> derived were characterized as beans with maturation complete in opposite behavior were the others cross.

PC406

## PHYSICOCHEMICAL COMPOSITION OF GREEN AND ROASTED BEANS AND BEVERAGE OF COFFEE TO SAME GEOGRAPHICAL GROWING ORIGIN

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Aassocation of coffee quality to their local production is a way to differentiate and aggregate value to their production. Northeast Region Parana, Brazil is known for its high quality coffee which is obtained through a production system fully established. Relationship between the composition of coffee and the physicochemical properties of roasted coffee and beverage with local growing was established in this study. It has determined the physicochemical composition of green and roasted coffees and beverage characteristics in coffees semidry and natural cherries harvested in 16 municipalities of this region. Environmental conditions allowed development of the beans (size, density) and the formation of compounds related to the quality (sugar, caffeine, chlorogenic acids, proteins, lipids and phenolics). These compositions were consistent with patterns of beans completely developed. Loss of weight, density and color parameters evaluated in roasted coffee and acidity of the beverage have showed significant correlations with the green coffee composition. PC1 (26%) and PC2 (17%) of Principal Component Analysis were formed mainly by characteristics of roasted coffee and beverage. Compounds of green beans showed lower contributions to the formation of these components, indicating homogeneity of physicochemical composition of the coffees. Although this study has revealed different characteristics of roasted coffee and beverage and this fact was not enough to make clear separation of the local growth and post-harvest processing. Therefore, under standard conditions of post-harvest and roasts process the coffees will present their own characteristics and they can be traded in uniform batches originating of this region.

PC407

## SENSORIAL PROFILE OF COFFEES PRODUCED IN NORTHEAST REGION OF PARANA-BRAZIL

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Free Choice Profile (FCP) technique has been used for sensorial evaluation of foods for which each assessor uses its own vocabulary to adequately describe the product. Commercial quality of coffee when associated with the growing conditions is manifested mainly in the sensory attributes of the beverage. Northeast Region Parana-Brazil is known for high quality coffee. The aim of this study was to characterize the sensorial profile of the coffees in this region by FCP. Thirty-two semidry and 21 natural coffees were evaluated, and were harvested in 16 municipalities (2008 harvest). Data obtained from 15 assessors were analyzed by Generalized Procrustes Analysis and the first-two dimensions explained 33 and 13% of the variance between samples. Attributes as coffee aroma and taste, sweet, sour, bitter and green aroma and taste were found and contributed to the horizontal separation in the scatter plot. Second dimension involved the attributes related to appearance (color and brightness) and texture. Positive sensorial attributes were found in all the municipalities without a local association of attributes and showing the uniformity of the sensorial profile in the region. No separation of attributes between the processes was observed as expected, probably due to different modes of conduct them. Standardization of procedures for to eliminate the negative attributes founded, will allow the expression of the special attributes already present in these coffees. Thus the homogeneity of the sensorial profile of the coffees in this region contributes to its trade with the local identity.

PC408

## CAFFEINE AND TRIGONELLINE IN ESPRESSO AND FRESH-BREW COFFEE – IMPACT OF GRIND SIZE, WATER TEMPERATURE AND COFFEE/WATER RATIO

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Coffee brews induce antibacterial and anti-adhesive effects on *Streptococcus mutans*, the main pathogenic organism for dental caries in humans. Caffeine and trigonelline are responsible for this effect, just as nicotinic acids and chlorogenic acids are [1, 2]. Andueza et al. studied trigonelline and caffeine as physical-chemical parameters for the quality of espresso. They reported the influence of the coffee/water ratio, the water pressure, the grinding grade, and the water temperature [3].

Recently, our working group investigated the influence of the particle size, the water temperature, and the coffee/water ratio on the cafestol content and the C-5-HT content, substances of the coffee oil in Espresso and Fresh-Brew coffee [4]. The aim of this study was to analyse the behaviour of the water-soluble substances caffeine and trigonelline under the same conditions as used for the liposoluble substances. The coffee brews were prepared using a vending machine provided with an Espresso unit and a Fresh-Brew unit. The caffeine and trigonelline contents were detected with an RP-HPLC system equipped with diode array detector. It could be shown that in addition to the particle size, the coffee/water ratio is the most important factor influencing the water-soluble matters in the prepared coffee brews.

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## PC409

### STERYL GLUCOSIDES IN THE COFFEE PLANT

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Over the past years phytosterols have achieved more importance due to their beneficial properties. In a number of scientific articles it was reported that the phytosterols reduce the cholesterol levels and have anticarcinogenic effects [1]. Furthermore, an immune modulating effect was described [2].

In coffee, the total sterol content varies between 1.5 to 2.4%; with 5.4%, an even higher content was reported by Nagasampagi. These values represent only the free and esterified sterols [3]. Moreover, in other plants, steryl glucosides have been identified as a third group. Steryl glucosides were analysed, for instance, in wheat, flaxseed, soybeans, and pumpkin seeds [4, 5]. All these plants as well as Coffea belong to the class of the Magnoliatae.

The aim of this study was to develop a method to analyse steryl glucosides in green and roasted coffee beans as well as in different parts of the coffee plant. The extraction was carried out by accelerated solvent extraction and followed by solid phase extraction on silica gel. Three fractions were obtained: a first fraction with the sterols esterified with fatty acids, a second fraction with the free sterols, and a third fraction with the steryl glucosides. The quantification of the sterols was accomplished by GC-FID after silylation. Additionally, the GC results of the sterols were compared with those of the RP-HPLC-method developed.

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## PC410

### TRIGONELLINE AND HMF Δ PARAMETERS TO STUDY THE COFFEE PROPORTION IN COFFEE DRINKS

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The popularity of coffee drinks has increased during the past years. These chilled coffee drinks consist of milk (at least 70%) and, at most, of 30% of other ingredients such as a coffee preparation, sugar, rheological additives, cocoa, flavourings, and sometimes caffeine [1]. The added coffee proportion ranges between 0.8 to 19% and may be a solid or liquid coffee extract or a coffee brew.

To study the coffee proportion in coffee drinks it was necessary to find a suitable analyte. Due to the water solubility of trigonelline that component is an ideal analyte for quantification. In samples from the German market trigonelline ranged between 8 mg and 25.9 mg/ coffee drink. The coffee drink with a part of 19% of a coffee preparation showed the highest trigonelline content. The trigonelline and the HMF (hydroxymethylfurfural) content were analysed using an RP-HPLC system equipped with DAD.

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## PC411

### EFFECT OF STORAGE TEMPERATURE ON THE SHELF LIFE OF PACKED ROAST AND GROUND COFFEE

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Delivering a positive consumption-experience of roast and ground coffee at the consumer's home is highly desirable and closely associated with its freshness. Therefore the aim of this study was to simulate storage of coffee packages at home prior to their opening and evaluate the effect of storage temperature on the possibility to prolong its freshness. The study used highly sensitive analytical method capable of monitoring even minute differences of oxidation at very early stages of the coffee shelf life. Roast and ground coffee - Turkish style (250\_m mean granular size), was packed under inert conditions in 100g pillow packages by industrial production line. Samples of the packed product were stored at -18°C, 4°C and ambient temperature for eight month period. The samples were monitored by GC-MS analysis for freshness (Oxidation-Index) and volatiles content, at 30 days intervals. Discriminative and preference sensory analyses were conducted by a trained panel in conjunction to the analytical analyses. Differences among the treatments were observed by GC-MS at early stages with the onset of oxidation, whereas sensory recognition was followed later on. The Oxidation-Index showed a clear correlation to storage temperature with oxidation rate lower at -18°C<4°C<Ambient.

## **PC412**

### **CONTENT OF CARBOXYLIC ACID-5-HYDROXYTRYPTAMIDES (C-5-HT) IN DECAFFEINATED ROASTED COFFEE: INFLUENCE OF DECAFFEINATION Process**

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The thin waxy layer covering the green coffee bean is mainly constituted by the so called carboxylic acid-5-hydroxytryptamides (more correctly  $^5\text{N}$ -alkanoyl-5-hydroxytryptamides, C-5-HT). These compounds stimulated several studies because they have been suggested as candidate stomach irritants with ulcerogenic effects on the gastric mucosa. It is well known that C-5-HT are partially thermally decomposed by roasting and by steam treatment. It is also known that a decrease in C-5-HT content can be observed by decaffeinating the green coffee beans, being dichloromethane (DCM) process more efficient than the supercritical  $\text{CO}_2$  one.

In the present paper we report on the influence of the decaffeination process on the content of C-5-HT in roasted coffee beans. Same lot of green Arabica has been decaffeinated by: water, dichloromethane, ethyl acetate and supercritical  $\text{CO}_2$  processes and the C-5-HT content has been determined on the roasted products. On the basis of the experimental results, the possibility to use the total amount of C-5-HT as a marker of decaffeination process has been explored by analyzing a number of decaffeinated roasted coffees purchased on the market.

## **PC413**

### **HOW DO WE MEASURE FRESHNESS OF ROASTED COFFEE? EXPLORING FRESHNESS INDICES OF WHOLE AND GROUND COFFEE.**

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With the growing demand for specialty coffee and the rising consumer awareness of quality in the cup, it is becoming increasingly important to establish objective and quantitative measures of coffee quality. Cupping is today a widespread technique to evaluate aroma and quality of coffee. Yet, cupping mostly focuses on defects, while specialty coffee is expected to be free of defect. Hence, in our most recent research, the focus has been on developing quantitative analytical measures for positive coffee quality attributes, aimed specifically at specialty coffees. Among others, this includes making the concept of freshness measurable [1, 2]. Here we report on the development and application of instrumental techniques with the aim of establishing chemical and physical indicators of freshness.

Chemical indicator – freshness-indices: A range of different freshness-indices will be discussed. This includes specific ratios between volatile compounds that are either typical for freshly roasted coffee or an expression of degradation and oxidation processes, analyzed by HS GC-MS. We will report on results during storage for

up to one year, for a range of commercial single serve capsule systems (ground coffee), as well as for whole roasted beans in packagings with different barrier properties.

Physical indicator – Crème: The Crème is a typical attribute associated with an espresso and linked to the freshness of the roast and ground coffee. Here we will report on a novel and precise methodology to measure the amount of CO<sub>2</sub> within freshly roasted coffee, and estimate the freshness.

Combining both indicators, we will establish an approach to quantify freshness. This will be integrated into a larger platform for the objective description of coffee quality.

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**PC414**

### HARDNESS OF THE COFFEE GREEN BEAN RELATES TO THE ENVIRONMENTAL-DRIVEN SENSORIAL QUALITY OF THE BEVERAGE

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Coffee prices are based on qualitative parameters and the markets that best remunerate the product have become more demanding on sensorial quality, valuing specialty coffees.

Throughout berry ripening and seed development, several compounds are developed, both through *de novo* synthesis or chemically modification, thereby producing unique flavor, acidity, and taste attributes with direct impact on the quality of the beverage. These quality attributes are related to the presence and abundance of certain amino acids, carbohydrates, volatile and non-volatile compounds, phenolic acids and biogenic amines. Some of these compounds, like caffeine, trigonelline, caffeoic and chlorogenic acids (CGAs) are known modulators of beverage quality, but many others remain unknown. Hence, a good knowledge of the differences in the chemical composition of green coffee is mandatory for understanding differences in premium quality products.

The coffees from Minas Gerais, Brazil, have been distinguished in international markets and a close association between the beverage sensory quality and the specific microenvironment in which they are grown and beans are yielded, namely altitude, has been established. However, the precise mode by which the interaction with the environment determines the final quality of the produce is still to be elucidated.

In this work, we measured caffeine and CQAs isomers (3-, 4- and 5-CQA) by high-performance liquid chromatography (chemical) and determined green bean hardness using a TA-XT Texture Analyzer (physical) in beans from 24 samples characterized by "Specialty Coffee Association of America" parameters (sensory evaluation), obtained from 3 classes of altitude (<1000 m, 1000-1200 m and >1200 m). Principal Components Analysis was carried out to disclose the variables that most relate to the quality of the beverage. The first and second components, contributing to 66.2% of total variation, establish a close relationship between hardness of the green beans and sensory quality. Moreover, 5-CQA, but not 3-CQA and 4-CQA, contents show higher levels on high-rated sensory grade coffees.

The influence of temperature deviations during plant development, in the cell wall composition has been reported. Moreover, quality-related phenolic species can be linked to the cell wall and CQAs are known to be intermediates in lignin biosynthesis in the 'core phenylpropanoid pathway'. The results reported here, associating, for the first time, green bean hardness with beverage quality, sound with these observations.

PC415

ATTENUATED TOTAL REFLECTANCE FOURIER TRANSFORM  
INFRARED SPECTROSCOPY (ATR-FITR) FOR DISCRIMINATION  
BETWEEN ROASTED COFFEE AND ADULTERANTS**REIS, Nádia, OLIVEIRA, Leandro S., FRANCA, Adriana S.**

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Ground roasted coffee has been the target of fraudulent admixtures with a diversity of cheaper materials (twigs, coffee husks, spent coffee grounds, roasted barley corn and others) because it presents physical characteristics (particle size, texture and color) that can be easily reproduced by roasting and grinding a wide variety of biological materials (Oliveira et al., 2009). Recent studies have shown that FTIR-based methods have been successfully applied in the food industry, in association with food quality evaluation, with a few applications focusing on roasted coffee (Franca and Oliveira, 2011). Among the commonly employed FTIR sampling techniques, attenuated total reflectance (ATR) can be employed for either solid or liquid samples. Thus, the objective of this work was to evaluate the potential of this technique for simultaneous discrimination between roasted coffee and the following adulterants: coffee husks and roasted corn. Coffee beans and adulterants were submitted to batch roasting in an oven at temperatures ranging from 200 to 260°C, with roasting conditions established according to color measurements ( $L^*a^*b^*$  color parameters) in comparison to commercially available roasted coffee samples. Multivariate statistical analysis was performed in order to verify the possibility of discrimination between coffee and adulterants. Principal Components Analysis based on normalized spectra indicated separation of the samples into the three specified categories. Classification models were developed based on Linear Discriminant Analysis and recognition and prediction abilities of these models were 100%, with the samples being separated into three groups: coffee, coffee husks and corn. Such results confirm that ATR-FTIR presents potential for the development of an analytical methodology for detection of adulteration in roasted and ground coffee.

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**PC416**

## **DETECTION OF COFFEE HUSKS AND ROASTED CORN IN ADMIXTURES WITH ROASTED COFFEES BY FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)**

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Not only is Brazil the largest coffee producer and exporter, but also it is one of the largest consumers in the world. Because of the way coffee is consumed, i.e., an infusion of ground roasted beans, the product of consumption is quite vulnerable to adulteration with other roasted grains and beans, such as corn and barley. Also, coffee by-products such as spent coffee grounds and coffee husks are commonly used for adulteration of ground roasted coffee since, after roasting, they become difficult to be detected by visual inspection and common routine analytical methods (Oliveira et al., 2009). Recent studies have shown that FTIR-based methods have been successfully applied in the food industry, in association with food quality evaluation, with a few applications in coffee analysis (Franca and Oliveira, 2011). Thus, the objective of the present study was to develop an analytical methodology for the verification of coffee adulteration with roasted corn and coffee husks. The methodology was based on FTIR analysis of several samples of coffee beans, corn and coffee husks, after roasting and grinding. Coffee beans and adulterants were submitted to batch roasting in an oven at temperatures ranging from 200 to 270°C. Roasting conditions were established based on color measurements ( $L^*a^*b^*$  color parameters) in comparison to commercially available roasted coffee samples. Samples of coffee were adulterated with varying proportions of corn and coffee husks (1, 2, 5 and 10%). Multivariate statistical analysis was performed in order to verify the level of discrimination between coffee and adulterants. Principal Components Analysis provided separation of the samples into four groups: coffee, coffee husks, corn and adulterated samples. Classification models were developed based on Linear Discriminant Analysis, with the adulterated samples being satisfactorily separated from pure coffee. Such results confirm that FTIR is an appropriate analytical methodology for detection of adulteration in roasted and ground coffee.

Acknowledgements: The authors acknowledge financial support from the following Brazilian Government Agencies: CAPES, CNPq and FAPEMIG.

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**PC417**
**QUANTIFICATION OF ROASTED AND GROUND DEFECTIVE COFFEES IN ADMIXTURES WITH NON-DEFECTIVE COFFEES BY ATR-FTIR AND CHEMOMETRICS**
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Research interest on defective and low quality coffee beans has intensified over the past years, given the increasing awareness on the negative aspects they impart to the quality of the coffee beverage (Craig et al., 2012). In the present study, Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR) and Partial Least Squares Regression (PLS) were used to quantify defective coffees in blends with non-defective coffees. Defective (black, immature and dark sour) and non-defective Arabica coffee beans, manually picked, were roasted, ground and sieved ( $0.25 < \text{particle diameter} < 0.39 \text{ mm}$ ). Blends were prepared by mixing defective and non-defective coffees, ranging with %defects ranging from 3% to 30%, (10 blends for each defect). Samples (2g) were analyzed, in five replicates, by ATR-FTIR, using a horizontal ATR sampling accessory (ATR-8200HA) equipped with ZnSe cell. Pure non-defective coffee was also analyzed. All spectra were recorded within a range of  $4000\text{--}700 \text{ cm}^{-1}$  with a  $4 \text{ cm}^{-1}$  resolution and 20 scans, and submitted to background subtraction. In order to enhance the results, two pre-treatments were applied to raw data: 3 points baseline correction and 1<sup>st</sup> derivative Savitzky-Golay algorithm. Multivariate regression by Partial Least Square (PLS) was performed to develop the predictive models. Table 1 presents the calibration and validation parameters of the models obtained with 10 factors. For the models constructed with blends of black and non-defective coffee, baseline correction provided higher degree of accuracy with the lower standard error of calibration and prediction and the highest  $R^2$ . In the case of dark sour and immature blends, 1<sup>st</sup> derivative provided higher degree of accuracy. Results indicate that FTIR-PLS presents potential to be used as a fast and reliable analytical tool for the evaluation of coffee quality.

Table 1 – Calibration and validation parameters for the prediction models

Models	Pre-treatment	Calibration		Prediction		
		RMSECV (%)	RMSEC (%)	$R^2$	RMSEP (%)	$R^2$
Black	Baseline correction	4.344	1.212	0.982	2.397	0.970
Black	1 <sup>st</sup> derivative	5.832	1.206	0.982	4.735	0.832
Dark Sour	Baseline correction	3.336	1.024	0.998	17.484	0.922
Dark Sour	1 <sup>st</sup> derivative	2.918	0.544	0.920	2.993	0.997
Immature	Baseline correction	5.979	2.371	0.936	5.241	0.730
Immature	1 <sup>st</sup> derivative	4.206	1.088	0.987	3.953	0.867

Acknowledgements: The authors acknowledge financial support from CNPq, Brazil.

**References:**

Craig, A.P., Franca, A.S., Oliveira, L.S. 2012. Discrimination between defective and non-defective roasted coffees by diffuse reflectance infrared Fourier transform spectroscopy. *LWT Food Science and Technology*, 47, 505-511.

PC418

## POTENTIAL OF ATR-FTIR FOR DISCRIMINATION BETWEEN DEFECTIVE AND NON-DEFECTIVE ROASTED COFFEES

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The determination of food quality and authenticity are major issues in the food industry. Most instrumental techniques required for food quality assessment are time demanding, expensive and involve a considerable amount of manual work. Therefore, there is a need for new and rapid analytical methods, as infrared spectroscopy, which is a fast, reliable and non-destructive. This methodology, coupled with chemometric data analysis techniques, has been successfully applied to food quality evaluation (Franca and Oliveira, 2011), and recently, to coffee quality evaluation prior to roasting (Craig et al., 2012). In view of the aforementioned, the objective of this work was to evaluate the potential of Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR) for the discrimination between defective and non-defective coffee beans after roasting. Two different methodologies were developed and evaluated, one based on the analysis of ground coffee samples and the other based on the analysis of brewed coffees (5g coffee mixed with 25 mL water, 20 min contact at 90 °C, filtered). Defective (black, immature, light and dark sour) and non-defective Arabica coffee beans, manually picked, were roasted under nine different roasting conditions, ground, sieved, and analyzed by ATR-FTIR, using a horizontal ATR sampling accessory (ATR-8200HA) equipped with ZnSe cell. Using air background for ground samples and distilled water background for brewed samples, spectra (4000-700 cm<sup>-1</sup>) were obtained in absorbance units at a resolution of 4 cm<sup>-1</sup> and 20 scans. First derivative was applied to data using Savitzky-Golay algorithm and Principal Components Analysis (PCA) was performed. In the case of ground coffee, PCA provided discrimination of the samples into two groups: (a) non-defective and light sour and (b) black, immature and dark sour. In the case of brewed coffee, samples were separated into three groups: (a) non-defective and light sour, (b) black and some light sour outliers and (c) immature and dark sour. The results of this work indicate that, except for light sour beans, it is possible to discriminate between defective and non-defective coffees by ATR-FTIR, using either solid or liquid samples. It is important to consider that analysis of ground coffees is faster and simpler, being more suitable for development of routine methodologies.

Acknowledgements: The authors acknowledge financial support from CNPq, Brazil.

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**PC419**

**OXIDATION OF LIPIDS AND PROTEINS IN GREEN ARABICA COFFEE DURING THE STORAGE PERIOD**

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Changes in the coffee beverage quality during the storage of the green beans had been attributed to the reactive compounds from the lipids oxidation. It is supposed that the loss of the quality could also be due to the modifications of other grain compounds as a consequence of the lipids oxidation. In this work, modifications in the natural (dry process) and pulped natural (semi-dry process) coffee beans composition were investigated following the changes in the concentration of the free fatty acids, thiobarbituric acid reactive substances (TBARS), protein carbonyl groups and 5-cafeoylquinic acid (5-CQA) during the storage for 15 months under controlled conditions. Results showed an increasing in the free fatty acids concentration and a decreasing in the content of the 5-CQA during all the storage period. The TBARS content increased until the third month, whereas the content of the protein carbonyl groups increased until the sixth month in the pulped natural coffee and until ninth month in the natural coffees. The results confirmed the oxidation of the coffee protein and lipid fractions during the storage period and the possible relationship between the oxidation process and the amount of free fatty acid into the grain.

Acknowledgements

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**PC420**

**HIGH-RESOLUTION  $^1\text{H}$ -NMR CHARACTERIZATION OF STIMULATED WHOLE HUMAN SALIVA BEFORE AND AFTER ESPRESSO COFFEE DRINKING**

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Saliva is a complex biological fluid involved in food oral processing and in food sensing. It is present as a thin film covering the surface area of our mouth. Saliva is responsible for the high resistance to infections of the oral cavity. Its action is manifested both through a physical mechanism because it ensures the self-cleaning of the oral cavity and the wetting of oral mucosa, and through the antibacterial activity ensured by the presence of specific components. Coffee beverage, particularly espresso coffee, is known to strongly interact with human oral cavity. This interaction leads to several peculiar characteristics of the beverage including long lasting aftertaste, tongue and teeth staining ability and anti-cariogenic potential thanks to its anti-adhesive action against *Streptococcus mutans*, which is considered as the major causative agent of human dental caries. In order to put in evidence possible molecular interactions between oral cavity and coffee compounds, the combined mechanically stimulated secretions of the major (parotid, submandibular and sublingual) and minor salivary glands known as "stimulated whole saliva" of 5 healthy subjects have been characterized before and after espresso coffee consumption. Espresso coffee sample was the same for all the subjects. By adopting

a strict saliva sampling protocol, the characterization has been performed by high-resolution  $^1\text{H}$ -NMR. This technique offers many advantages over alternative time-consuming, labor-intensive analytical methods since it permits the rapid, non-invasive, and simultaneous study of a multitude of components present even in the lack of knowledge on the chemical composition prior analysis. Before espresso coffee drinking, the CPMG-NMR spectrum of stimulated whole saliva shows many components present in all samples. Main peaks present in the spectra have been assigned by  $^1\text{H},^1\text{H}$  COSY,  $^1\text{H},^1\text{H}$  –ROESY and  $^1\text{H},^{13}\text{C}$ -HSQC experiments while the CPMG-NMR experiments allows a better comparison of spectra as it filters out protein components altering the baseline. The concentration of some species widely varies from subject to subject. In order to highlight the changes in the saliva composition, the mathematical difference of CPMG-NMR spectra recorded after and before espresso coffee consumption has been studied and compared with the espresso coffee spectrum. Caffeine persists in saliva more than other coffee compounds, after consumption. Chlorogenic acids and trigonelline are also retained but in minor extent. Interestingly the content of some saliva metabolites after espresso coffee consumption shows a remarkable interindividual variability. Whether this variability is related to the variability observed before coffee drinking or it is induced by coffee drinking has to be ascertain with further studies.

PC421

### POTENTIAL USE OF STABLE ISOTOPES AS AN INDICATOR OF COFFEE QUALITY

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Coffee prices are based on quality parameters, so high price markets have become more demanding, valuing specialty coffees. The environment, apart from influencing production and the development of coffee trees, has also a fundamental role in determining the characteristics of the beans and the formation of “key” compounds of gourmet coffees. The identification of these compounds may be a strong indicative of a high quality beverage. Organic acids, carbohydrates and proteins in the raw beans are parameters commonly used to assess quality spatial distribution. Indeed, carbon and nitrogen carbon isotopic compositions of plant material are linked to environmental conditions, especially altitude latitude, water availability and nutrients, during the plants’ growth. Recently, stable isotopes have been applied to determine the geographic origin of coffee beans showing that it is possible to use this technique to distinguish coffee from different geographic origins. The aim of his work was to apply carbon and nitrogen stable isotope analysis to distinguish green coffee seeds harvested at different altitudes of the Serra da Mantiqueira region in Minas Gerais state, Brazil. Moreover, we also showed that the coffee isotopic signature ( $_{^{13}\text{C}}$  e  $_{^{15}\text{N}}$ ) was also significantly correlated with sensorial analyses of the coffee beverage and the environmental characteristics of the coffee fields.

**PC423**

**POTENTIAL OF SOME COFFEA CANEPHORA COFFEES  
FOR INDUSTRIAL USES**

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Traditionally, coffee grains have been mainly used for coffee beverages and as a caffeine source for medicine and food industries. Nowadays they have also been considered as raw material for other nutraceuticals and cosmeceuticals ingredients.

In this work the potential industrial use of some *Coffea canephora* coffee grains under selection at the Agronomic Institute of Campinas was evaluated. The content of caffeine, 5-caffeoquinic acid (5-CQA) and soluble solids in the endosperm as well as the beverage quality were considered for that.

Concentration values ranged from 2.2 up to 4.2% (db) for caffeine, 29.9 up to 35.7% (db) for soluble solids and 5.4 up to 8.8% (db) for 5-CQA. The overall quality of evaluated beverages was between 75.2 and 83.5 in a 100 points full scale. High acidity and flavors like fruit, flowers, vanilla, nuts, caramel, honey, chocolate and strawberry were perceived in the beverages..



PC424

VENEZUELAN COFFEE FROM BISCUCUY: THE FIRST  
SENSORIAL EVALUATION OF ITS AROMA POTENTIAL

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In Venezuela, producing coffee around the town of Biscucuy is traditional. The production area is located in the Andean piedmont, on the municipality of Sucre, in the state of Portuguesa. This area is the second coffee producing zone in Venezuela with a production of 9000 tons per year (about 10% of the national production). Some 15000 families are dependent on this production. With the aim of increasing their income, the producers decided to create a cooperative with the target of producing a specific quality coffee so to value their know-how. This coffee growing area is highly contrasted in terms of cultivars (Bourbon, Cattura, Catuai, Typica...) and altitude (from 700 m to 1450 m). The purpose of this study is to get a first insight in the aroma potential of these coffees, quite unknown in the coffee world till now.

The aroma potential was determined by sensorial profiles. Coffee samples were taken from farmers, members of the "Grano de Oro" cooperative. As members, they respect a technical procedure defined and negotiated by themselves. A special care is taken to the harvest; only ripe cherries at the beginning of the harvest period are picked up. Then coffee pulp is removed, the beans are washed and sun dried. Once dried, it is stored at the cooperative to be roasted and sold.

The samples illustrate the diversity of the 24 locations according with various factors such as cultivars, altitude, fertilization and shade. The sensorial evaluations are carried out by 10 panellists, trained in the sensorial laboratory of CIRAD, France. The descriptors are those usually used to describe the basic tastes and the specific flavours of coffees. Sensorial profiles are built.

Coffees from Biscucuy area are defined by a balance between acidity and bitterness. In some cases, a green or a fruity note is well perceptible.

Analyses of variance bring to light factors influencing the sensorial profiles:

- an effect of cultivar, especially in the case of Typica and Bourbon cultivars quite different from the others,
- a low effect of an increasing altitude on acidity, contrary to the usual observation in other coffee producing countries.

Besides picking out the potential of the Biscucuy area coffees, this study shows the originality of the factors which influence the sensorial characteristics of these coffees. The variability of the cultivars seems to involve differences in the sensorial profiles much more important than the variability due to the altitude. Based on these preliminary results, a project has been set up to go further so as to identify and quantify all the factors impacting the sensorial quality of the Biscucuy area coffees.

PC425

OPTIMIZATION OF THE PHENOLIC COMPOUND EXTRACTION  
FROM GROUND AND BREW COFFEE

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Several ways to extract phenolic compounds from coffee samples have been found in the literature. However, many differences are observed in the described conditions, such as the solvents, time, temperature and number of extractions batches. Due to that, the evaluation of the different parameters of the extraction is necessary to obtain an optimized method and to ensure the best condition to achieve a large yield of phenolic compounds. The aim of this study was the optimization of the extraction of phenolic compounds from roasted coffee ground and brew.

A full factorial experiment was designed to evaluate the following factors: 1 or 2 sequential batchs of extractions, water, 50% methanol or 80% methanol as solvents and 20, 40 or 60 minutes of standing before the centrifugation of the extracts (Table 1). Particularly for the ground coffee, an additional factorial experiment was designed to evaluate three more factors, as follow: 3 or 4 sequential batches of extraction, 0 or 20 minutes of standing before the centrifugation of the extracts and room or 90°C temperature of water.

Table 1: Studied factors for the extraction of phenolic compounds (brew and ground coffee)

Factors	Levels
Extraction	1 or 2
Solvent	Water, 50% Metanol, 80% Metanol
Standing time (min)	20, 40, 60

The amount of phenolic compounds was estimated by the classical Folin-Ciocalteu spectrophotometric method, and the treatment that presented the highest value of absorbance was considered the best condition of extraction. Statistical analysis were performed by ANOVA, followed by the Tukey test and the Student t test ( $\alpha=0,05$ ).

No difference was observed for the coffee brew considering the extraction factors that were evaluated in the 18 treatments ( $p>0,05$ ). It was concluded that the brewing process was able to extract the most of the phenolic compounds, and an additional extraction step was not necessary for the extraction from the coffee brew. However, for the ground coffee, the best treatment employed 3 sequential extractions with water at 90 °C, followed by centrifugation without any pause between extractions.

The guarantee that the largest possible amount of the phenolic compounds was extracted is relevant for the food and nutraceutical industry, which should take advantage of the antioxidant property of phenols. Although the phenolic extract is recognized as a mixture of phenols soluble in the solvent system, the standardization of the extraction factors enables a better comparison of the yields of phenolic compounds from different samples.

PC426

## CHANGES IN FLAVOR CHARACTERISTICS OF A CHILLED-CUP COFFEE BEVERAGE DURING STORAGE

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Changes in flavor characteristics during storage of a chilled ready-to-drink black coffee beverage were quantitatively investigated by analytical sensory evaluation, gas chromatography /olfactometry (GC/O), and GC/mass spectrometry (GC/MS).

Espresso coffee samples brewed from arabica coffee beans were aseptically filled in plastic cups with a straw at Morinaga's plant. Samples for sensory evaluation were stored at 10°C for 0, 1, or 2 months, while the ones for GC/O and GC/MS analyses were stored for 0, 0.5, 1, or 2 months. The cups had gas-barrier and shading properties, and the headspace in the cups was replaced with N2 gas when the samples were filled.

First, sensory evaluation was performed by 14 expert panelists (eight males and six females) who had worked for a coffee-roasting company. Each panelist sampled three samples stored for 0, 1, or 2 months using the straw. One- and 2-month-old samples were subjected to a 7-point sensory descriptive analysis for hedonic rating, flavor intensity, and 17 sensory terms. Each sample was compared with the standard (0-month-old) sample, which was given four points. Tukey's honestly significant difference (HSD) test of the sensory data showed a significant decrease ( $p<0.05$ ) in scores of hedonic rating and six terms: balance, body, mildness, roast flavor, chocolate, and bitterness during storage. In addition, data showed a significant increase ( $p<0.05$ ) in flavor intensity and eight terms: soy sauce aroma, lightness, green aroma, fruitiness, floralness, mocha flavor, berry flavor, and thinness during storage. Principal component analysis (PCA) of the sensory data revealed that the change in overall flavor from 0- to 1-month-old samples was larger than that from 1- to 2-month-old ones.

Second, volatile compounds of retronasal aroma (RA), which contribute mainly to flavor perception of beverages consumed with a straw, were examined using an RA simulator (RAS). The RAS volatiles of samples stored for 0, 0.5, 1, or 2 months were captured by a solid phase microextraction fiber (50/30 µm divinylbenzene/Carboxen™/polydimethylsiloxane), and analyzed by GC/O (CharmAnalysisTM). The GC/O analyses revealed 20 odorants and changes in 16 identified compounds were analyzed by GC/MS. Tukey's HSD tests of the peak areas showed that 12 compounds decreased significantly during storage. In addition, PCA of the GC/MS data demonstrated that the overall volatile profile from 0- to 1-month-old samples changed more than that from 1- to 2-month-old ones, supporting the PCA results obtained from the sensory data.

**PC427****QUALITY EVALUATION OF COFFEE EXTRACTS CONCENTRATED  
USING VARIOUS METHODS**

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Several coffee concentration methods were investigated to manufacture high-quality coffee extract concentrate as an ingredient for coffee beverage products. Coffee extract was concentrated by progressive freeze-concentration, reverse osmosis (RO) concentration, or column extraction-concentration methods. The concentrates were evaluated by sensory and instrumental analyses.

Coffee extract of 5.3° brix (CE) was brewed with hot water (100°C) from arabica coffee beans using a column extractor, cooled to 10°C, and then concentrated to about 8.2° brix by progressive freeze-concentration and RO concentration methods. In addition, another coffee concentrate (extract) of 7.8° brix was brewed from the same coffee beans using a 1.5-times longer column extractor. Sensory ranking tests for similarities between the standard sample (CE) and each concentrate sample diluted to 1.5° brix (10°C) were carried out by 11 analytical panelists (10 males and one female). In addition, diluted samples were analyzed by gas chromatography/mass spectrometry (GC/MS), a taste sensing system TS5000Z, and an electronic nose system αFOX4000. Furthermore, coffee beverages with milk and sugar, which contained the same quantity of coffee solids from each coffee concentrate, were subjected to a 7-point sensory descriptive analysis for hedonic rating and 13 sensory descriptors by the 11 panelists. Each beverage sample was compared with the standard beverage sample containing CE, which was given four points.

Similarity ranking obtained from sensory tests, volatile profile by functional groups from GC/MS data, and principal component analyses of responses from the taste sensing system and the electronic nose system showed that the coffee concentrate created via the progressive freeze-concentration method was the most similar to the CE, and that the quality change with this method before and after concentration was the smallest among the three concentration methods. Similar results were obtained from sensory analysis of coffee beverages with milk and sugar.

**PC428****EVALUATING WHOLE CUP EXPERIENCE IN GOURMET COFFEE  
BY USING DYNAMIC SENSORIAL METHODS**

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Gourmet coffee beans meet perfect physical quality and specific taste profiles which are obtained through interplay of plant variety, soil, climate and processing. The art of blending, roasting and extraction of such gourmet coffee beans allows the development of unique, rich and complex sensory profiles.

Traditionally, in cup coffee description is obtained using monadic profiling. However, this methodology does not give a dynamic view of the whole cup experience.

In the current study we have applied a modified Temporal Dominance of Sensations (TDS) methodology aiming at differentiating 12 gourmet espresso coffees beyond the classical QDA tasting, and providing new

information on the dynamics of coffee tasting over time. Additionally, we tried to use these data to further define complexity of gourmet coffee. The modified TDS is based on whole cup consumption where panelists drink the espresso in 7 sips, giving for each sip the dominant attribute.

TDS has been shown to give new and additional information on espresso aromatic descriptions. Different TDS profiles are obtained across products, allowing further differentiation between products that have a close sensory profile when assessed through QDA. It is observed that roasted notes are mainly found in the first sip while aromatic notes such as cereal, fruity and cacao appear and vary all along the consumption.

The current study shows not only that dominant attributes vary along the consumption of one cup, we have also observed that for some coffees it was difficult to find a consensus on one dominant attribute for each sip. We suggest that these findings could be indicators to help define complexity of our gourmet coffees.

**PC429****KEY AROMA MARKER COMPOUNDS LINKED TO BLEND  
SPECIFICITY IN NESPRESSO COFFEE**

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Coffee aroma is very complex, involving more than 1000 volatile compounds (1). Several studies (2-4) have shown that only about 25 can be considered as key impact odorants, being mainly responsible for roast and ground coffee aroma. Although the odor qualities and perception thresholds of the impact odorants are well described, their individual contribution to the aroma of such a complex mixture like coffee is still quite unclear, amongst other due to interactive sensory or release effects.

Recently, untargeted and targeted studies were performed to relate coffee volatiles to sensory perception and thus get a deeper understanding of the contribution of important aroma and taste compounds to the overall aromatic coffee profile (5, 6). An advanced predictive model was established correlating quantitative data of key odorants with sensory descriptors from an expert panel. This model generated valuable insights into the link between key aromatic markers and different blend specificities. Yet, the (statistical) correlations were sometimes not consistent with the flavor quality of some individual compounds.

Therefore, in this study a qualitative and quantitative aroma gap analysis was performed between pure roast and ground coffees having a distinct sensory profile, using a variety of sensory directed instrumental techniques such as GC/O, GC-MS and GCxGC-TOFMS. With this combined analytical approach, key aromatic markers having a significantly different concentration between the various coffees were identified and quantified (so-called aroma gap). Knowing this aroma gap, a series of spiking experiments was performed in reference coffees to prove the causal link between key aromatic markers and sensory attributes and thus to modulate the coffee aroma into a distinct sensory direction.

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## PC430

THE POSSIBLE EFFECT OF EMPTY LOCULE TO CUP TASTE ATTRIBUTES ON GUINEAN X CONGOLESE POPULATION OF ROBUSTA COFFEE (*Coffea canephora*)

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Guinean (G) and Congolese (C) groups of Robusta coffee have been known for their distinct cup taste profile. Several reports only revealed the difference of cup taste profile due to different genetic background without mentioning any specific traits contributed to the distinctness of cup profile. On the other hand, the phenomenon of empty locule was strongly assumed involves in the regulation of transportation of assimilate that possibly gives effects to the cup taste profile. Therefore, a study on correlation of empty locule to cup taste attributes was conducted. Data records were carried out for three years over one reciproc G x C populations consisted of 42 and 45 plants each, respectively. From 18 cup taste attributes observed, empty locule performed consistent significant positive correlations to the intensity of flavor attribute for two consecutive years of data records ( $r = 0,233$  and  $r = 0,278$ ) as well as for the average data of the three years observation (0,315). Empty locule also performed a positive correlation to astringent attribute ( $r = 0,233$ ) at a certain year, in contrast it performed a negative correlation to clean cup attribute ( $r = -0,211$ ) in other year. Cluster analysis to find out the different genetic background of empty locule characteristic revealed three groups corresponded to Congolese, Guinean and the group that not belong to the two groups. Generally, the Congolese group has higher proportion of empty locule than that of the Guinean one. But, this difference of empty locule characteristic between Congolese and Guinean was only detected in a certain year due to the long dry season. The last group showed the highest proportion of empty locule consistently than that of the other two groups.

**Key words:** *Coffea canephora*, Congolese, Guinean, empty locule, cup taste.

## PC431

## ANALYSIS OF COFFEE BEVERAGE COMPOSITION IN THREE ROASTING DEGREES USING LCMS-IT-TOF

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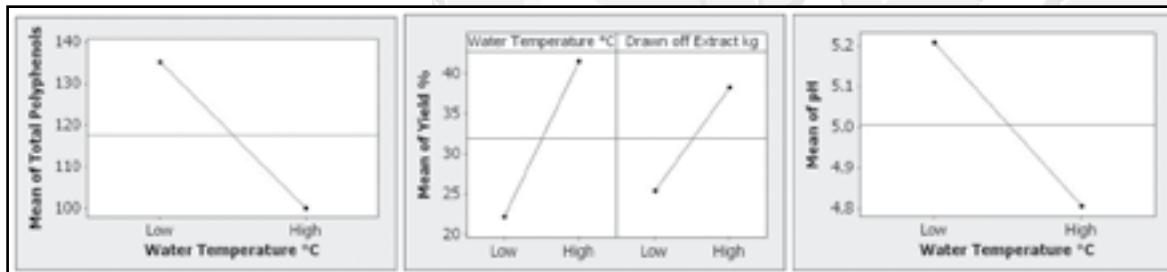
Beverages of four cultivars of *Coffee arabica* and one cultivar of *Coffea canephora*, roasted at light, medium and dark degrees, were analyzed by LCMS-IT-TOF System (SHIMADZU, JP). The samples were introduced in a HPLC system, nebulized and ionized at atmospheric pressure using the ionization probe ESI, in the positive and negative modes, working at high resolution and high mass accuracy. The four cultivars of *Coffea Arabica* and the cultivar of *Coffea Canephora* cv. Conillon presented similar total m/z ions in the LC-MS chromatograms for the different roastings, but the last species can be distinguished from the others by a higher content of furoylquinides, especially at medium roasting. The similarity is confirmed by ions m/z compositions

of the brews at different roasting degrees. A lot of known and unknown compounds present in the coffee brew contribute for making up the flavor of coffee infusion. However, Arabic coffees presented similar composition as well as similar components concentration. Canephora coffee practically presented same components of Arabica but in very different concentrations. For the medium roast, almost all components detected in positive mode mass chromatogram for Canephora coffee presented higher concentration than those of Arabica; on the contrary, in negative mode, also almost all components detected of Arabica brews presented higher concentration than those of Canephora. Without using standards, the amount of each component could be accomplished during the roasting process. Further, the exact mass of a lot of unknown molecule was determined and, in a few cases, molecular formula was suggested.

**PC432**
**COFFEE EXTRACTION PROCESS: YIELD, PH AND ANTIOXIDANT CAPACITY STUDIES.**
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Once the roasted coffee is obtained, the extraction process is the main operation in the production of soluble coffee because is there where the final sensorial and chemical characteristics of the instant product are defined. This research studied three variables in the extraction process: drawn off extract, feed water temperature and process flow and their effects in the antioxidant activity, pH and the yield of the process. A replicated full factorial experiment design was performed in an extraction pilot plant. 16 runs in all the experiment were done with Arabica Colombian coffee with 25-26 color (L) in Hunterlab scale. The results indicate that when high yield is the target, high water temperature and high drawn off extract are required. High values of antioxidant activity (Total Polyphenols, FRAP and ABTS) and pH are found when the process is set in low water temperature. The water flow did not affect any of the studied parameters. The feed water temperature is the main variable on the coffee extraction process and modifies all the characteristics of the final product.



Figures: Main Effect: Total Polyphenols (mg GAE/g soluble coffee), Yield (%) and pH.

**PC433**

**SENSORY PROPERTIES OF UNDER-ROASTED  
COFFEE BEVERAGES**

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Characteristics of both green and roasted coffee have been extensively investigated highlighting the deep modifications of chemical and sensory properties induced by roasting process. The influence of roasting degree and roasting process on sensory properties of coffee beverages has been widely studied. Sensory profile of beverages prepared by using green coffee has also been investigated, albeit not extensively. In early roasting stages –under roasting conditions- non-enzymatic browning is only partially developed, aroma is almost completely contributed by unaffected precursors and pyrolysis is just at its beginning. The effect of these conditions on sensory properties of coffee beverages has not yet been investigated. The goal of the present study is to fulfil the gap between green and roasted coffee through the definition of a set of sensory attributes describing the sensory profile of beverages prepared by using under-roasted coffee (e.g. thermally treated under non-conventional conditions).

*Coffea arabica* from two different geographical origins (Brazil and Guatemala) was thermally treated (temperature ranging from 140°C to 165°C for a total of 6 different samples) for 20 minutes in a pilot 10 kg roasting plant. Each coffee sample, characterized by a set of physical measurements (moisture, total weight loss and colour), was used to prepare beverages by means of a plunger coffee maker. The sensory profile of samples was described by a panel of 14 assessors, with no prior experience in coffee sensory evaluation, by using the conventional descriptive analysis. The relationships between coffee thermal treatment and sensory properties of the samples were investigated. Due to the wide variability in the sensory profile of the samples, the recognisability of the obtained beverages as coffee has also been studied. Results indicate that when non-enzymatic browning is not fully developed, the sensory attributes used to describe beverages obtained by conventional roasted coffee are not appropriate. The new set of sensory attributes developed in the present study should be seen as a tool to describe beverages obtained from coffee treated by under roasting conditions. Finally, minimal thermal treatment conditions leading panellists to elicit descriptors used to describe the sensory properties of beverages from conventional roasting conditions were defined.

PC434

## GREENHOUSE GASES EMISSIONS OF GREEN COFFEE PRODUCTION IN THE STATE OF MINAS GERAIS, BRAZIL: MEASUREMENT AND MITIGATION

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In recent years, the debate about environmental impacts and the sustainability of agricultural products has increased. Consumers are more and more concerned about the quality of food products and now looking for those with a low environmental impact, with a particular attention to carbon emissions. There are few studies regarding the greenhouse gases emissions associated with the Brazilian green coffee production. Located in the southeast region, Minas Gerais is the largest coffee-growing State in Brazil. It accounts for nearly 70% of the national coffee production. The objective of this study was to determine the main greenhouse gases (GHG) sources and to measure the carbon footprint of coffee production in the State of Minas Gerais. Three coffee farms located in the three typical production regions of Minas Gerais were selected: Cerrado Mineiro (CM), Matas de Minas (MM) and Sul de Minas (SM). Data from crop years 2009/2010 and 2010/2011 were considered. The carbon emission sources considered within the coffee farm were mobile and stationary combustion, nitrogen and organic fertilizers, lime and electricity. The upstream emissions related to the production and transport of agricultural inputs have not been accounted. Total emissions were different in the three different regions. However, besides the total emissions during a crop year, it is important to consider the emissions per unit of green coffee and per area cultivated with coffee in order to give a more accurate representation of the impacts in the production system. Total emissions have been therefore weighted by quantity of green coffee produced and by production area. Results show that the major source of carbon emissions was nitrogen soil fertilization. Fuel consumption for farm operations and lime application are also shown to be important. Electricity was not significant as most of the energy supply in Brazil comes from low GHG emission sources (e.g. hydroelectric and biomass). Additionally, some mitigation strategies related to nitrogen fertilization were proposed, such as the substitution of urea for lower GHG emission sources (e.g. ammonium nitrate) and the correction of fertilization rates and methods. This study is to be considered as a pioneering initiative in Brazil and it intends to provide baseline carbon footprint data, upon which emissions reduction plans and further research can be built. With these results it will be possible to design management strategies to promote sustainability along the coffee production chain and to add value to the final product.

## PC435

EVOLUTION OF PHYSICOCHEMICAL AND ORGANOLEPTIC  
PROPERTIES OF BREWED COFFEE DURING STORAGE RELATED  
TO GREEN COFFEE VARIETY AND ROASTING DEGREE

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Coffee is a beverage that holds complex taste, aroma and flavor properties that are influenced by several parameters such as coffee variety, origin, roasting and preparation methods. Following extraction, physicochemical modifications occur and alter organoleptic qualities of coffee.

The aim of this study is to track the "ageing" of coffee beverage through physicochemical and organoleptic analyses, and link it to green coffee variety and roasting degrees. We studied the influence of coffee variety (Arabica or Robusta) together with that of post-harvest treatments. To this end, three types of green coffee were used: dry-processed Arabica, wet-processed Arabica and dry-processed robusta.

For each type of green coffee, various 3 roasting degrees were used (light, medium and dark). For all samples, coffee was brewed using a single extraction method (filter coffee).

Evolution of the chemical composition (organic acids, chlorogenic acids and lactones of chlorogenic acids), pH, turbidity and colour of brewed coffee was followed during 45 days of storage. Sensory analyses were performed in parallel.

This study allowed us to access to the evolution of both organoleptic and chemical parameters during brewed coffee storage. Notably, we confirmed the influence of both roasting conditions and coffee variety on the global quality of brewed "aged" coffee.

## PC436

POTENTIAL OF BIOGENIC AMINES TO EVALUATION  
OF IMMATURE COFFEE QUALITY

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Immature coffee fruit processing contributes to a high amount of defective beans, which determines a significant amount of low-quality coffee sold in the Brazilian internal market. Unripe coffee processing will be tested, taking the levels of bioactive amines as criteria for evaluating the extent of fermentation and establishing the differences between processing methods. The beans were processed by the dry method after being mechanically depulped immediately after harvest or after a 12 h resting period in a dry pile or immersed in water. Seven bioactive amines were quantified: putrescine, spermine, spermidine, serotonin, cadaverine, histamine, and tyramine. The results confirm that peeling immature coffee can decrease fermentation processes while providing more uniform drying, thus reducing the number of defects and potentially increasing beverage quality.

**PC437**

**ACRYLAMINE IN IMMATURE COFFEE: FORMATION  
AND POTENTIAL STRATEGIES OF CONTROL**

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José O.\*\***

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The presence of the “green” defect is associated with natural coffee produced in Brazil due to factors arising from the harvesting, processing and drying techniques. Immature coffee beans resulting from this process has a lower commercial value because it contains defective grains. During immature coffee processing, different processes result in unripe fruit with different physical-chemical composition. Asparagine levels become relevant in coffee composition because asparagines concentration is higher in immature fruit. The amino acid asparagine is the main precursor of acrylamide, a potentially harmful substance to human health. Different post-harvest processing and degrees of roasting will be compared with the aim of minimizing acrylamide formation in roasted unripe coffee beans. The results may be promising for the control and formation of this substance.



**PC438**
**DETERMINATION OF HEAVY METALS IN GREEN COFFEES AND THEIR RESPECTIVE BEVERAGES**

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The fact that Brazil is the worlds largest producer, exporter and the second largest consumer of coffee evidences the necessity and importance of analyzing the qualitative aspects of green coffee and the drinks they originate. Moreover, few scientific studies were performed to quantify the inorganic elements in coffee, especially those considered heavy metals. The objective of this study was to assess the levels of these chemicals in grains and in the drinks they originate. On a previous work done with samples from 30 properties in Londrina, Parana, Brazil (15 samples of sandy soils and 15 of clayous soils), grains of four properties were selected. The grains chosen were the ones which had the highest levels of heavy metals (Table 1), being two samples of each type of soil. The green grains selected were roasted and ground. To extract the beverage, eight grams of roasted coffee powder were used to produce 50 ml of the drink. Filter paper and hot distilled and deionized water at 90°C (194°F) were used for the infusion. The minerals evaluated were the same quantified in the grains. The quantification of chemical elements chromium (Cr), cobalt (Co), Nickel (Ni), lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) were performed on samples by the technique of Inductively Coupled Plasma Atomic Emission Spectroscopy, Thermo Jarrell-ash ICAP 61E (ICP-AES), model spectrometer. The contents of the minerals examined suffered variation between the sites analyzed, possibly due to anthropogenic action because of the intensity and type of agriculture products used. Of the metals initially present in the grains, Cr, Co, Ni, Pb and Cd were not transferred to the drink, Zn, Mn, Cu and Fe were present in the beverages, but in very reduced quantities. The results evidenced that the heavy metals were strongly retained in the roasted coffee powder.

Table 1. Concentration of heavy metals in green beans and its coffee beverages and chemical elements after extraction thorough filter paper.

Elements	Concentration found <sup>2</sup> (mg. kg <sup>-1</sup> )							
	Property 1		Property 2		Property 3		Property 4	
	Green Grain	Beverage	Green Grain	Beverage	Green Grain	Beverage	Green Grain	Beverage
Cr	1.14	0	0.88	0	1.34	0	1.52	0
Co	0.47	0	0.46	0	0.43	0	0.80	0
Ni	0.39	0	0.32	0	0.30	0	0.89	0
Pb	1.79	0	2.02	0	1.30	0	1.30	0
Cd	0.02	0	0.03	0	0.07	0	0.07	0
Zn	7.15	0.200	6.88	0.200	6.88	0.150	7.25	0.350
Mn	20.18	0.450	18.63	0.400	23.23	0.475	96.45	2.500
Cu	11.98	0.100	13.40	0	14.40	0.050	12.10	0
Fe	34.18	0.200	30.25	0.100	45.98	0.200	31.85	0.225

**PC439****CHARACTERIZATION OF FATTY ACIDS PROFILE AND OXIDATIVE PROCESS IN GREEN COFFEE BEANS DURING STORAGE**

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The storage of coffee beans is considered a critical phase for the beverage quality maintenance. It is very known that during storage the coffee beans suffer a fast deterioration due several biochemical and sensory alterations culminating in loss of quality and undervalued the coffee price. Some chemical alterations detected in the green coffee bean are usually associated to oxidative processes, in special the oxidation of lipids that contributed to form unpleasant flavors and undesirable aromas in roasted coffee beans, depreciating the cup quality. However, it is not yet well understood how this process occur and how extent is its effects on sensory quality. The objective of this research was to characterize the profile of fatty acids in green coffee beans and to evaluate the influence of these profile changes on the beverage quality during the storage period. Arabica coffee samples obtained by dry (natural coffee) and wet (pulped coffee) processing procedures were submitted to drying in concrete yard and in a mechanical dryer operating with hot air drying at 40°C until the grains reached moisture content of 11% (w.b.). When the dried fruit coffees and the parchment coffees reached hygroscopic equilibrium they were packaged and stored at lab conditions without environment control. The beans were hulled and graded by size in several screens with circular and oblong perforations and samples of flat beans retained over screens up to 16/64 inch sieve size and free of damaged or defective beans were submitted to lipids extraction by cold press being the free fatty acids identified and quantified by gas chromatography. The sensory analysis was performed according the Specialty Coffee Association of America (SCAA) procedures. To evaluate the effects of the post-harvest processing on coffee bean quality the analyses were done during one year at zero, three, six, nine and twelve months after the storage. It was identified and quantified twelve fatty acids and into the lipid composition the main acid saturated was the palmitic acid and among the unsaturated acids prevails the linoleic acid followed by oleic acid. The variations in the fatty acids profile contributed for significant sensory changes, particularly in the natural coffee processing procedure, which presented unpalatable flavor and undesirable aroma, independent of the drying method.

PC440

GREEN BEAN PHYSICAL CHARACTERISTICS AND BEVERAGE  
QUALITY OF PROMISING LOW CAFFEINE ARABICA COFFEE  
GENOTYPES IN BRAZIL**SAATH, Reni<sup>\*</sup>, GIOMO, Gerson S.<sup>†</sup>, SILVAROLLA, Maria B.<sup>\*</sup>, LOBATO, Mary T. V.<sup>\*</sup>, BORÉM, Flavio M.<sup>\*\*</sup>**<sup>\*</sup>Agronomic Institute (IAC), Campinas-SP, Brazil; <sup>\*\*</sup>Federal University of Lavras (UFLA), Lavras-MG, Brazil.

In the specialty coffee market are preferred coffee beans that present high cup quality and good physical characteristics. It is reported that intrinsic sensory coffee quality depends on a combination of factors including the green bean chemical composition and green bean physical characteristics. Thus specialty coffees with distinctive cup quality and rarest or predominant flavors constitute a good opportunity to grow up the income of coffee farmers, being benefit for all the coffee chain. Besides sensory profile, green bean size and green bean shape & make are physical characteristics so important to determine the coffee price at market, where generally large beans receive better prices than small beans. However the relations between these green bean physical characteristics and the sensory profile of coffee as well as its effects on beverage quality have not yet been fully elucidated. In this context arabica coffee cultivar that presents genetic potential to produce coffees beans with differentiated cup quality constitute an important alternative for coffee breeding programs aiming to improve cultivars for specialty coffee production. Considering the scarcity of information concerning the coffee genotype effects on sensory profile and green bean physical characteristics in Brazil this study aimed to evaluate the size and shape of green beans and beverage quality of several *Coffea arabica* genotypes under selection at Agronomic Institute, concerning to identify progenies with good physical characteristics, distinctive cup quality and naturally low level of caffeine content in the beans. The experiment was carried out at Agronomic Institute (IAC) in Campinas-SP during the 2010/2011 crop year. It were analyzed fifty five coffee bean samples from different genotypes in F<sub>2</sub> and F<sub>1</sub>BC<sub>1</sub> generations between wild coffee genotypes naturally caffeine-free and elite Brazilian commercial cultivars, being each treatment constituted by the respective progeny. Healthy and ripe coffee fruits were hand harvested and prepared by semi washed process (pulped natural coffee) and the wet parchment coffees were sun dried over elevated screens until the grain reached moisture content of 11%. After hulling the clean coffee beans were classified by size in several screens with circular perforations of 19, 18, 17, 16, 15, 14 and 13/64 inches and three screens with oblong perforations of 11, 10 and 9 x ¾ inches to determine the percentage of retention. Coffee samples from up to 15 inch sieve size without defective beans were submitted to sensory analyses according to Specialty Coffee Association of America (SCAA) procedures. The results indicated that there are differences for both green bean size and cup quality among the progenies. This confirms the existence of genetic variability for physical and sensory traits into the studied genotypes, indicating the feasibility of selection of new cultivars in the future. Some progenies showed qualitative characteristics better than the commercial cultivars used as check, revealing the real intrinsic genetic potential of these genotypes to produce naturally low caffeine coffee beans with sensory profile differentiated by flavor and aroma.

## PC441

## SENSORY QUALITY ALTERATIONS AND ACTIVITY OF LEA PROTEINS DURING THE COFFEE BEANS STORAGE

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The intrinsic quality of coffee is an important factor for the price determination at market. The main quality changes of coffee beans during the storage period are associated to fluctuations in temperature and relative humidity of the storage environment that affect the intensity and speed of the grain deterioration. The oxidative process occurs when there is imbalance between the antioxidant defense system and the production of reactive species of oxygen and nitrogen. If these reactive substances are predominant, they react with other proteins, carbohydrates and lipids, causing changes in the mechanisms of cell homeostasis that leading to loss of functionality. This study aimed to characterize the LEA proteins profile in *Coffea arabica* L. beans and to verify its relationship with the loss of sensory quality during the storage period. Arabica coffee samples obtained by dry (natural coffee) and wet (pulped coffee) processing procedures were submitted to drying in concrete yard and in a mechanical dryer operating with hot air drying at 40°C until the grains reached moisture content of 11% (w.b.). When the dried fruit coffees and the parchment coffees reached hygroscopic equilibrium they were packaged and stored at lab conditions without environment control. The beans were hulled and graded by size in several screens with circular and oblong perforations and samples of flat beans retained over screens up to 16/64 inch sieve size and free of damaged or defective beans were submitted to lab analyses. The sensory analysis was performed according the Specialty Coffee Association of America (SCAA) procedures. The LEA proteins extracting, the electrophoresis and the visualization of bands were done according the methods described by Alfenas (1998), Alfenas (2006) and Alfenas et al. (1991), respectively. To evaluate the effects of the post-harvest processing on coffee bean quality the analyses were done during one year at zero, three, six, nine and twelve months after the storage. It was concluded that: a) the pulped coffee beans showed better cup quality than the natural coffee independent of the drying method; b) the LEA proteins profile was influenced by post-harvest processing procedures; c) the intensity and variation of the LEA proteins had strong association with the sensory coffee quality; d) the cup quality of pulped coffee was less affected by the interaction effects of processing, drying and storage period than the natural coffee.

**PC442**
**PRINCIPAL COMPONENT ANALYSIS OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF COFFEE SUBMITTED TO DIFFERENT POST-HARVEST PROCESSES**

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The present work aimed to develop a methodology in order to aid the cup test by means of principal component analysis (PCA) of physical and chemical characteristics of coffee submitted to different postharvest procedures. Thus, lots of coffee with parchment and cherry coffee were dried under temperatures of 40, 50 and 60 °C; however, samples dried at 40 °C were added by 0, 10, 20 and 30 % of green coffee. After twelve months of storage, samples were subjected to sensorial analysis and analyses of color, electrical conductivity, bulk density, one thousand mass and gas chromatography. By means of comparison between PCA of physical and chemical properties of coffee grain and PCA of sensorial analysis, it was observed a similarity among analyses (Figures 1a and 1b). PCA's "a" and "b" explained more than 75 % of total data variance and differentiated coffee samples into eight groups (A to H). A, B and C groups are: samples dried with parchment at 40, 50 and 60 °C; D, E and F groups are: cherry coffee dried at 60, 50 and 40 °C without addition of green beans; G and H groups are cherry coffee dried at 40 °C with addition of 10 % and above 20 % of green beans, respectively. After twelve months of storage, through analysis of Figure 1, it was noticed differences among samples according to the post-harvest process in which coffee was submitted. By means of comparison between Figures 1a and 1b, it was concluded that PCA of physical and chemical characteristics was compatible to sensorial analysis, allowing this procedure to aid the cup test, permitting less subjectivity of this test.

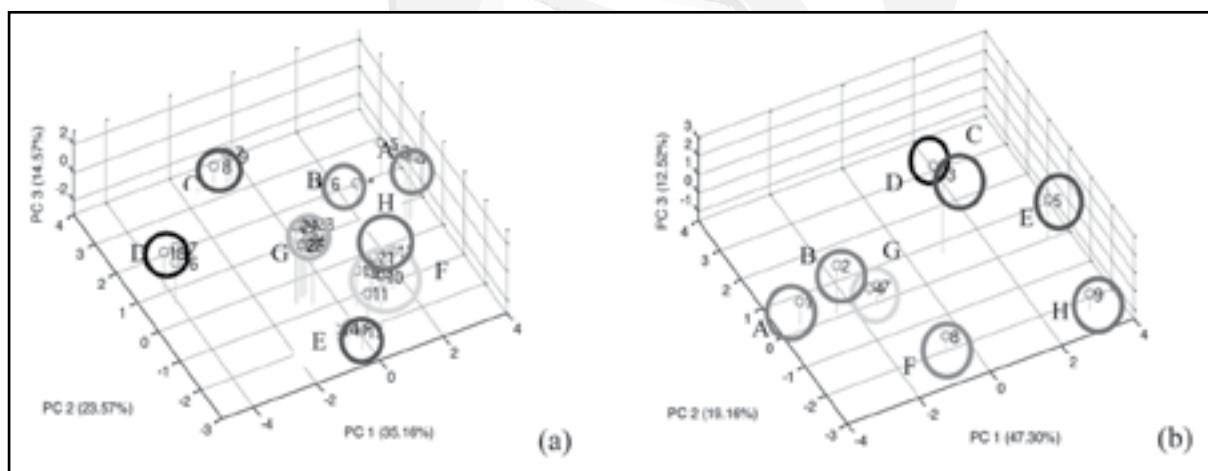


Figure 1: Principal component analysis generated by means of (a) physical and chemical properties and (b) sensorial analysis of coffee grain after twelve months of storage.

PC443

## EVALUATION OF GREEN BEAN PHYSICAL CHARACTERISTICS AND BEVERAGE QUALITY OF ARABICA COFFEE CULTIVARS IN BRAZIL

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In the specialty coffee market are preferred coffee beans that present good physical characteristics and high cup quality with distinctive sensory attributes, emphasizing the fragrance, aroma, flavor, sweetness, acidity, body and overall score. Coffee quality evaluation done in several countries using specific sensory methodology and trained cuppers have indicated that Bourbon variety frequently show high beverage quality with outstanding sensory attributes, revealing the real genetic potential of the Bourbons to improve the coffee quality. Considering that Bourbon variety is recognized by its intrinsic cup quality this research was carried out to evaluate physical characteristics of the green beans and to describe the sensory profile of some *Coffea arabica* L. cultivars under selection at Agronomic Institute aiming to identify promising cultivars for specialty coffee production in Brazil. It were analyzed twenty four arabica coffee cultivars, including three Mundo Novo, four Catuaí, one Yellow Icatu, two Caturra, two Red Bourbon and twelve Yellow Bourbon progenies. The experiments were performed during three crop years (2009, 2010 and 2011) in the Northwest Sao Paulo State, Brazil, using a Randomized Complete Block Design with three replications for each treatment. Healthy and fully ripe fruits were selectively handpicked and prepared by semi washed processing procedures (pulped natural coffee). The wet parchment coffees were sun dried over elevated screens until the grain reached moisture content of 11%. After hulling the clean beans were classified by size in screens with circular perforations of 19, 18, 17 and 16/64 inches. Coffee samples from up to 16 inch sieve size without defective beans were submitted to sensory evaluation according to Specialty Coffee Association of America (SCAA) procedures. The results showed that: a) there are physical and sensory quality differences among Brazilian commercial cultivars and Bourbon progenies; b) although good green bean physical characteristics do not necessarily correspond to high sensory quality, new Bourbon cultivar could be selected for better physical quality; c) the flat beans percentages were affected by Genotype more than by Environment and the peaberry percentages were affected by Environment more than by Genotype; d) fragrance, aroma, flavor and overall sensory score were affected both by Genotypes and Genotype × Environment interactions; e) all studied cultivars showed similar and good cup quality but the highest overall scores were observed in Yellow Bourbon progenies; f) if the beverage quality is an important trait for specialty coffees production, new Bourbon cultivar should be selected with priority on sensory attributes. Considering that all coffees were from the same environmental and processing procedures, it is supposed that the prominent differences in physical and sensory quality could have occurred due genetic effects. The subsidiary aroma and taste, similar to chocolate, caramel, vanilla and fruit notes and high overall score observed in the sensory analysis of some Yellow Bourbon cultivar confirm the high quality potential of this genotype, indicating the possibility of genetic selection of plants with superior cup quality to attend the specialty coffee market demand.

**PC444**

## POTENTIAL OF YELLOW BOURBON VARIETY TO IMPROVE THE SENSORY QUALITY OF SPECIALTY COFFEES IN BRAZIL

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Nowadays Brazil is the world's largest producer and exporter of coffee. The environmental diversity, intensive coffee breeding and improved crop management techniques have contributed for this success. Considering recent advances in post harvest technology and other initiatives to improve the Brazilian coffee quality is reasonable to infer that Brazil presents strategic potential to supply the needs of the specialty coffee market in the coming years. To be considered a specialty coffee the green beans should present good physical characteristics and good cup quality with distinctive sensory attributes, emphasizing the fragrance, aroma, flavor, acidity, body and overall preference culminating in high final scores. Bourbon variety has been reported to present better cup quality, showing genetic potential to improve the coffee quality. In this research it was evaluated the sensory profile of some Yellow Bourbon progenies under selection at Agronomic Institute aiming to identify promising genotypes for specialty coffee production in Brazil. Thirty four *Coffea arabica* genotypes comprising of 31 Yellow Bourbon progenies and three commercial cultivars as control were evaluated in this study. The experiments were carried out during 2009/2010 and 2010/2011 crop years in the Northwest Sao Paulo State, Brazil, using a Randomized Complete Block Design with three replications for each treatment. Healthy and fully ripe fruits were selectively handpicked from seven plants of each genotype per plot and prepared by semi washed processing procedures (pulped natural coffee). The parchment coffees were sun dried over elevated screens to final moisture content of 11 to 12%. After hulling the flat beans were graded by size using four screens with circular perforations of 19, 18, 17 and 16/64 inches. Coffee samples graded up to 16 inch sieve size without defective beans were submitted to sensory evaluation according to Specialty Coffee Association of America (SCAA) procedures. The results obtained showed that: a) there are differences on beverage quality among Yellow Bourbon progenies and commercial cultivars indicating that is possible to selected genotypes for better sensory quality; b) fragrance, aroma, flavor, acidity, body, aftertaste, balance, overall impression and final score were affected primarily by Genotype and fragrance/aroma by Genotype × Environment interactions; c) all genotypes showed a normal good cup quality desirable for any arabica coffee variety but the highest values for acidity and overall score were observed in some Yellow Bourbon progenies; d) to improve the coffee quality new Yellow Bourbon cultivar should be selected based on specific sensory attributes; e) considering that all genotypes were from the same environment conditions and processing procedures, it is supposed that genetic effects were responsible for differences in sensory attributes; f) the perception of aroma and taste similar to chocolate, caramel, spicy, vanilla and fruit notes in some Yellow Bourbon progenies confirm the real potential of this genotype to improve the coffee quality in Brazil.

**PC445**

**POTENTIAL OF YELLOW BOURBON VARIETY TO IMPROVE THE GREEN BEAN PHYSICAL QUALITY OF SPECIALTY COFFEES IN BRAZIL**

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The Bourbon variety was introduced in Brazil from the Reunion Island around 1859 and became famous due its intrinsic cup quality. In the specialty coffee market are preferred coffees that present outstanding cup quality and beans with good physical characteristics emphasizing the size, density, shape and aspect. Several studies have indicated that Bourbon variety could present frequently better cup quality than other traditional commercial arabica coffee variety, confirming the intrinsic genetic potential of Bourbon to produce high coffee quality. However, information regarding green bean physical quality of Yellow Bourbon coffees is very scarce in the literature. Around 1932 Agronomic Institute starts the Bourbon variety selection culminating in the first Brazilian improved Bourbon cultivar named Red Bourbon IAC662 that was released in 1940. Almost at the same time it were identified some plants with yellow fruits and higher yield than Red Bourbon cultivar. These plants were selected and new cultivars named Yellow Bourbon IACJ2, IACJ9, IACJ10, IACJ19, IACJ20, IACJ22 and IACJ24 were released after 1945, which nowadays constitute the major Bourbon coffees in Brazil. Today Agronomic Institute has intensified researches into Bourbon Germplasm Collection aiming to identify promising genotypes to supply the needs of the Brazilian specialty coffee producers. In this research were evaluated thirty four arabica coffee genotypes comprising of 31 Yellow Bourbon progenies, one Red Icatu cultivar and two Yellow Mundo Novo advanced selections. Two experiments were carried out in 2009/2010 and 2010/2011 crop years in the Northwest Sao Paulo State, Brazil, in a Randomized Complete Block Design with three replications for each treatment. Healthy and fully ripe fruits were selectively handpicked from seven plants of each genotype per plot and prepared by semi washed processing procedures (pulped natural coffee). The wet parchment coffees were sun dried over elevated screens until the grains reached moisture content of 11%. After hulling the clean beans were classified by size using five screens with circular perforations of 19, 18, 17, 16 and 15/64 inches and three screens with oblong perforations of 12, 11 and 10 x ¾ inches. The results showed that: a) the percentages of flat and peaberry beans were affected both by Genotype and Genotype × Environment interactions; b) significant differences on green bean physical quality among the genotypes indicate the possibility of to select new Yellow Bourbon cultivar to improve the specialty coffee production in Brazil; c) the highest values of peaberry beans and the lowest values of large flat beans were observed in Red Icatu cultivar and Yellow Bourbon progenies, respectively; d) considering that all coffee beans were from the same environmental and processing procedures, it is supposed that the bean physical characteristics differences could have occurred due genetic effects. However, considering the natural biennial cycle of arabica coffee and the effect of Genotype × Environment interactions would be necessary to evaluate these genotypes during at least more two crop years. This will contribute to understand the real genotype effect on the green bean physical characteristics, avoiding any mistakes or inappropriate conclusions concerning the Bourbon coffee quality.

PC446

DESCRIPTIVE AND QUANTITATIVE SENSORY PROFILES  
THE COFFEE FROM SUCRE MUNICIPALITY PORTUGUESA  
STATE VENEZUELA

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Sensory quality of coffee depends on a number of factors ranging from planning to planting of the coffee to the method of preparation of coffee. In this paper we studied the quantitative descriptive sensory profiles of coffee Sucre municipality of Portuguesa state in Venezuela. The samples studied were mixtures of Arabica coffee beans harvested in the cooperative crop gold 2009-2010. The study of sensory profiling was performed by the analytical sensory panel laboratory belonging to the Research Center for Development (CIRAD) in Montpellier, France. Data were analyzed by Friedman test to determine the significance of the data and graphs. The quantitative profile of the attributes studied showed that the intensity of odor and the body of the coffee cups were the descriptors that were more important and a balance of acidity and sour descriptors. The coffee samples presented different descriptive sensory profiles of the attributes body, acidity, green, chemical and overall quality, while the attributes odor intensity, bitter, sour, fruity, woody, earth, chemical, fermentation, harsh and astringent were the same for all samples.

**Keywords:** coffee, sensory profile, descriptors.

**PC447**
**COPPER IN COFFEE GROWING ON DIFFERENT SOILS**

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Copper is considered heavy metal, but at low concentration is an essential nutrient for plant development. With the onset of rust that is disseminated by the coffee regions, has become widely used as fungicide and also applied as fertilizer. However, the copper may accumulate on the surface of agricultural soils and even in relatively low concentrations can be toxic to plants.

In Brazil, plant-available micronutrients in the soil can be determined by several chemical extractants, the most common of which are dilute acid and chelating solutions.

The objective of this study was to evaluate the effects of copper soil application for coffee plant, the availability of cooper extracted by chemical solutions and determine critical copper level in the soil for coffee plant. The research was conducted in Epamig's farmers locates in São Sebastião do Paraíso, clay soil, and Três Pontas, sand clay soil. The treatments consisted of four levels of copper: 0, 2, 4 and 8 kg.ha<sup>-1</sup> applied only at first year. Five extractors were used: Melich 1, HCl 0,1 mol.L<sup>-1</sup>, HCl 0,05 mol.L<sup>-1</sup>, DTPA and Mg Cl<sub>2</sub>. The copper soil levels were increased when Melich 1 and HCl 0,05 mol.L<sup>-1</sup> extractors were used in sand clay soil at first year. Soil Cu extracted by HCl 0,05 mol.L<sup>-1</sup> was correlated with copper leaf contents only in a clay soil. At second year, one year after application, there were significant residual effects of copper on the copper's soil concentration obtained whit HCl 0,1 mol L<sup>-1</sup> and DTPA extractants and on coffee production in a clay soil (Figure 1 and 2). A production increase was verified until 8kg.ha<sup>-1</sup> of copper applied. The data indicated that Cu critical level for coffee in these soil were 20 and 12,99 mg.dm<sup>-3</sup> whit HCl 0,1mol.L<sup>-1</sup> and DTPA extractors respectively. It was found that the methods have low accuracy in the evaluation of copper availability to plants. The coffee responded positively to application of copper in clay soils.

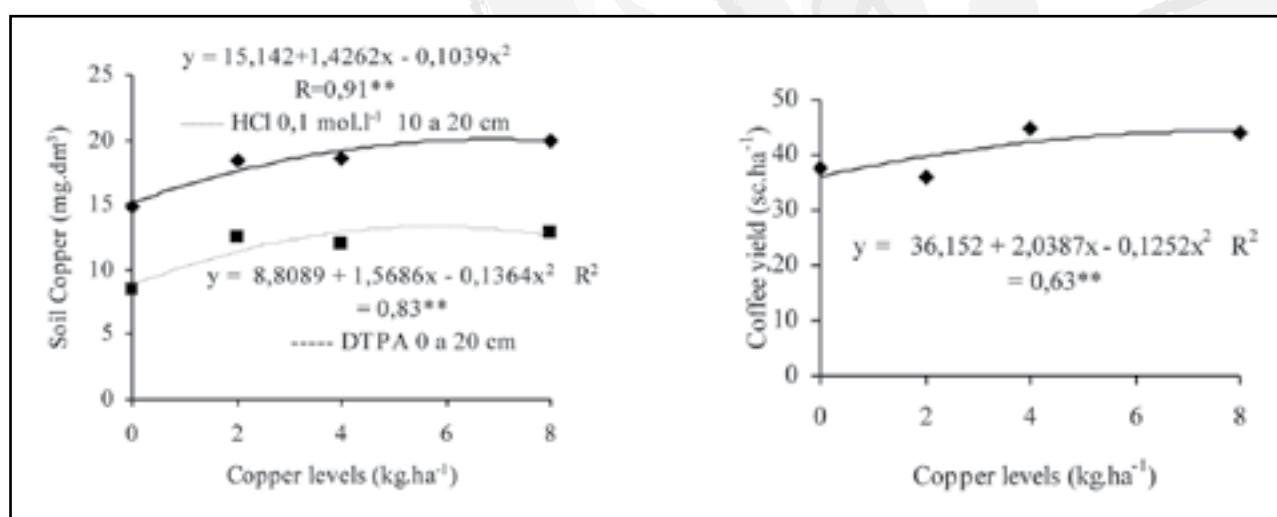


FIGURE 1 - Copper soil levels extract by HCl 0,1 mol L<sup>-1</sup> and DTPA one year after application in clay soil - São Sebastião do Paraíso.

FIGURE 2 - Coffee yield as function of Copper levels applied in clay soil - São Sebastião do Paraíso.

**PC448**

## **EFFECT OF ROASTING CONDITIONS ON SENSORY RESPONSE TO COFFEE BREW: EXPLORING CONSUMER PERCEPTION**

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The sensory characteristics of coffee beverages play an important role on coffee drinkers experience. Previous studies have reported that several factors affect coffee sensory properties, such as: plant varieties, growing region/conditions, processing, roasting levels, grinding size, and brewing methods. Extensive studies have been carried out to explore the relationship between those variables and the coffee aroma and flavor, as well as overall consumer acceptance in ground roasted coffee. However, only few studies have focused on the role of roasting conditions on brewed coffee. Besides, the majority of them either has used trained people to profiling samples, or investigated consumer liking. Although sensory profiling is a useful technique for the food industry in several steps of the process optimization, it is time consuming. Moreover, trained panels describe the product differently or take into account attributes that may be not relevant to consumers. Considering that the way consumers perceive the sensory characteristics of products is particularly important to the food industry in order to create products that meet consumer expectations, alternative methodologies have been developed to achieve this goal, and the check-all-that-apply (CATA) question is one of them. This study aimed at investigating the effect of roasting coffee conditions on sensory characteristics of the brews by consumers. Green coffee Arabic Brazilian beans were roasted in a plant scale semi-fluidized bed roaster at different temperature gradients to obtain three speed conditions (slow, medium and fast), and two roasting degrees (moderately light and dark), yielding six different types of beans. The beans were ground to medium grid and 57 coffee drinkers (at least one cup of black coffee a day: 21 males and 36 females, aged from 18 to 65 years old) participated in the study. They evaluated the six beverages in terms of liking, and also using CATA question, which comprised 20 hedonic and sensory attributes taken from the literature and previous studies developed at Embrapa Food Technology. They were related to *aroma* (characteristic, weak, burnt, chocolate, aromatic, sweet, fragrant, intense); *flavor, mouthfeel, and aftertaste* (characteristic, burnt, rubbery, stale, acid, very bitter, bad flavor, very astringent, intense residual flavor, unpleasant aftertaste); *texture* (low body, full-bodied). Data were analyzed using frequency of mention of each word of the CATA question by counting the number of consumers who used that term to describe each coffee beverage followed by Multiple Factor Analysis (MFA) on the frequency table. Consumer overall liking scores were considered as supplementary variable. The first two dimensions of MFA accounted for by 75.0% of the variance. The first dimension separated slow and fast speeds to obtain moderately light roasting degree from medium speed, and finally, dark roast for the three speed conditions (slow, medium and fast). Brews from moderately light coffees roasted at slow and fast speeds were described following the attributes: characteristic coffee aroma and flavor, aromatic, fragrant, sweet aroma, weak aroma, low body, which were positively correlated to overall liking. Brews from dark coffee roasted at slow and medium speeds were perceived by participants as having burnt aroma and flavor, rubbery, astringent, and unpleasant aftertaste. The results indicate that consumers perceived samples differently depending on roasting conditions.

**PC449**

**THERMAL STABILITY STUDY OF OCHRATOXIN A DURING ROASTING COFFEE (*Coffea arabica*)**

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Ochratoxin A (OTA) is a metabolite produced by species of *Aspergillus* and *Penicillium* and has been associated with nephrotoxic, immunotoxic, teratogenic and carcinogenic effects. Roasting coffee is thermal processes that have an effect on the OTA content. Before 1988 it was thought that the OTA was destroyed during roasting, nevertheless concentrations superior to the 20 ppb have been reported in commercial roasted coffee. Several reports concerning the roasting impact on OTA content in coffee beans have shown contradictory results. Such variability could be related to the different analytical conditions or roasting process or heterogeneity in toxin distribution. Some explanations for OTA reduction during roasting were suggested: isomerization into other diastereomers; the existence of reactions that "masked" OTA or rearrangements of the OTA molecule at the roasting temperatures. Because there are no conclusive data regarding the effect of roasting on OTA in grain and the need for scientific bases for establishing regulations for export of green coffee, the objective of this work was to study the impact of different types of roasting on the thermal stability of OTA in coffee and chemical elucidation of the transformation products.

Two samples of contaminated coffee (5.3 and 57.2 ppb of OTA) were roasted at 230°C using two methods: drum rotation (TR) and fluidized bed (LF). Samples were taken every 3 and 0.9 min from TR and LF respectively. Each sample was analyzed for OTA content. The results showed that the process by TR was more effective on OTA reduction than LF for a same degree of roasting with 67% OTA reduction against 36% for the medium roast. The thermal degradation rate of pure OTA and the OTA mixed with the components of coffee (5 sugars, 3 amino acids, caffeine and chlorogenic acids) were determined, showing that interactions took place dependent themselves on the conditions of pH and pKa values of the components tested, in this case by influencing by the reactivity and the rate of degradation of OTA. A transformation product (TP) was observed in the chromatograms obtained from the interaction of OTA with the components of coffee. A test of alkalinization and warming of pure OTA confirmed that the TP comes from the structural modification of the OTA molecule and is not a product of interaction with the natural components of coffee.

The TP was purified to carry out its chemical elucidation. The chemical nature of compound transformation and spectroscopic data such as UV-Vis ( $\lambda_{\text{max}}$ : 237nm), the affinity with the mobile phase of the OTA, the analysis of alkalinization (OTA regeneration phenomenon and TP), the analysis of stable isotopes (SIDA's) and the mass spectrum (molecular ion  $M^+$ : 420 m/z), suggest that the TP of OTA during the roasting process corresponds structurally to an analogue of OTA which retains its acidic carboxyl group and in accordance to fragmentation corresponds to the Hydroxi-Ochratoxin A (OH-OTA), as well as minor amounts of OTA and its isomers.

PC450

MORPHOLOGICAL AND MOLECULAR CHARACTERIZATION OF  
OCHRATOXIN A PRODUCING STRAINS OF *Aspergillus* ISOLATED  
FROM COFFEE (*Coffea arabica*)

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The section *Circumdati* is a group of organisms especially well known for its production of ochratoxin A (OTA). *A. ochraceus* is a member of this group and has attracted much interest by its role in the OTA contamination of coffee. Interestingly, several isolated have now been reidentified as *A. westerdijkiae*, so many of the species reported as *A. ochraceus* may indeed be *A. westerdijkiae*, so identification of the most common and often important species remains problematic due to the variability in the phenotypic characters. This has caused errors in the literature. New trends are based on a polyphasic approach using phenotypical characters together with physiology, multigene DNA sequences to a successfully identification. This work describes the results about type OTA producing strains isolated from coffee using polyphasic approach. In this way, we can elucidate the principal species polluting coffee.

Several OTA producing *Aspergillus* strains were isolated during different steps of post-harvest coffee processing (*Coffea arabica*). Morphological characterization was determined in CYA, CY20, and MEA medium and by Pitt identification keys. With ochre yellow colony almost all isolated strains did not grow at 37 °C, and were identified as *A. westerdijkiae* specie. ITS1-5.8S-ITS2 region (ITS rDNA) and β-tubulin gene (TB) sequences, usually reported, were obtained for molecular characterization. Furthermore we proposed another locci, that was the elongation 1 α factor (FE 1-α). DNA sequences were visually aligned using ClustalW2 and NCBI software. ITS rDNA sequence was searched for BLAST and showed a homology of 95 % with *A. ochraceus* and *A. westerdijkiae* species, meanwhile TB sequence showed a high reliably relation of 99-100% only with the *A. westerdijkiae* specie. FE 1-α sequence for species of section *Circumdati* is not reported yet, so relation was of 94-97 % with *A. terreus* and *A. fumigatus*, however FE 1-α analysis showed differences between strains that belong to the same species. This survey showed that *A. westerdijkiae* is predominant than *A. ochraceus* in coffee. This is not desirable because *A. westerdijkiae* is the highest OTA producing specie.

PC451

ANTIFUNGAL PROPERTIES OF LIPOFILIZED GREEN COFFEE  
CHLOROGENIC ACID

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Chlorogenic acid (CGA) extracted from Mexican green coffee beans (*Coffea arabica*) was esterified to alcohols of different chain length (methanol, butanol, octanol, and dodecanol). CGA and lipophilized CGA (L-CGA) antifungal activities were tested on five toxigenic moulds from the *Aspergillus* genus (*A. flavus*, *A. nomius*, *A. ochraceus*, *A. parasiticus*, and *A. westerdijkiae*) using the microdilution method and the minimum inhibitory concentrations ( $MIC_{50}$  and  $MIC_{90}$ ) were determined. All molecules presented antifungal activity, however, only dodecyl chlorogenate and octyl chlorogenate showed a  $MIC_{50}$  for all fungi. Octyl chlorogenate had a  $MIC_{90}$  for *A. flavus*, *A. parasiticus*, and *A. nomius*. Lipophilization improves hydrophobicity of CGA resulting in amphiphilic molecules with antifungal properties.

**PC452**

## **DEVELOPMENT OF PRIMER SETS FOR DETECTION OF CORN AND BARLEY IN ROASTED COFFEE BY REAL TIME PCR.**

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In the last years, the need for certification of origin and authenticity of foods increased the demand for sensitive and selective methodologies to guarantee the consumers' choice, which is not always attended due to different existing types of adulteration. In Brazil, two of the most common adulterants found in roasted coffee are corn and barley. The present study focused on the development and validation of real-time Polymerase Chain Reaction (PCR) systems for the detection of corn and barley. The DNAs from barley, corn and coffee *in natura* (standards) were extracted using a modified version of the DNeasy mini plant Kit protocol. Dilution series of DNA template were tested in 10 replicates for each primer to obtain standard curves. Coffee was roasted in a fluidized bed roaster, corn and barley were roasted in microwave oven. Roasted food samples were submitted to extraction with DNeasy kit/ buffer CTAB. DNA concentrations were determined in all *in natura* and roasted samples by spectrophotometer (Shimadzu UV-1800 Japan) at 260nm. Due to the inhibition of the reaction caused by low molecular weight compounds, such as phenols, carbohydrates, peptides and aromatic compounds, their presence was measured in the isolated DNA, using spectrophotometer at 230 nm, and the absorbance ratio 260:230 was calculated to evaluate the isolate quality<sup>1</sup>. The sequences used as templates to design the primers were obtained in the GenBank. Primer pairs were designed using the program GeneFisher2 and named ZEINA2 for corn and CEVADA3 for barley. The reactions were conducted by qPCR (SDS ABI Prism 7000 - Applied Biosystems USA) using the SYBR Green system (UK). Primers Specificity was determined by running new reactions with genomic DNA from rice, corn, wheat, coffee, soybeans and barley. The dissociation curve for CEVADA3 and ZEINA2 demonstrated that these primer pairs were specific for barley and corn detection. The ratio 260:230 in the *in natura* samples was = 1.6, which is considered of good quality (1). The Limits of Detection (LOD) for corn and barley DNA *in natura* were 8.1pg and 0.33pg, respectively, while the Limits of quantification (LOQ) were 5pg and 0.1pg, respectively. Reaction efficiency<sup>2</sup> was 113.4% and 95%, for corn and barley. Despite the low quality of the DNA isolate from the roasted foods (ratio 260:230 = 0.7)<sup>1</sup>, due to the Maillard compounds formed during roasting, which present similar structure to DNA nitrogen bases, it was still possible to detect them in roasted coffee even as residues of materials ground in coffee grinders.

(1) Murray et al, 1980. *Nucleic acid Research*, **8**:4321-4325.

(2) Lube et al, 2010. *Food Chemistry*, **118**, 979-986.

PC453

## CONTENTS OF CHLOROGENIC ACIDS AND LACTONES IN COURSE, MEDIUM AND FINE GROUND COFFEES BREWED BY DIFFERENT METHODS

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Innumerable potential health benefits have been reported for coffee in the literature. Chlorogenic acids (CGA) and their lactones (CGL) are important bioactive compounds in coffee. Their contents in coffee brews may vary according to blend composition of green beans, roasting method and degree, powder grid and the brewing method. Regarding the grid, the main basic ranges of particles size available in ground and roasted commercial coffees are conventionally called coarse, medium and fine. The aim of the present study was to evaluate the effect of brewing method and grid on CGA and CGL contents in brewed coffee. *Coffea arabica* and *Coffea canephora* beans were roasted to moderately-light and moderately-dark degrees (#75 and #45, respectively, AGTRON-SCCA) and ground to fine, medium and course grids (mesh 24, 20 and 14, respectively). A blend, composed of 80% *C. arabica* and 20% *C. canephora* roasted beans, was used for brews preparation at 10% (weight/volume), by the following methods: simple percolation (using paper, nylon and cloth filters); electric coffee maker (paper and nylon filters); espresso machine (Magic Comfort - Saeco, including or not pre-infusion), and Italian coffee pot. Brews were prepared in triplicate and analyzed by HPLC-DAD-reverse phase system according to Farah et.al. (2005) and results were compared by ANOVA, followed by Fisher test, with significance level of 95%. Eight CGA (three caffeoylquinic acids, two feruloylquinic acids, three dicaffeoylquinic acids) and two CGL (caffeoylquinic lactones) were quantified in the brews. In both roasting degrees, higher CGA and CGL contents were obtained from fine grid, followed by medium and course. For all grids, the Italian coffee pot was the most effective method to promote brews with higher total CGA and CGL contents (total of  $244.69 \pm 8.5$  mg/100mL fine grid, moderately-light), followed by electric coffee maker using paper and nylon filters ( $174.3 \pm 4.9$  mg and  $161.7 \pm 3.0$  mg/100mL, respectively) and espresso machine with and without pre-infusion ( $130.1 \pm 9.6$  mg and  $125.7 \pm 5.6$  mg/100mL, respectively). While excellent extraction results were obtained for caffeoylquinic acids, which are the major CGA in coffee, lower extraction of dicaffeoylquinic acids was obtained in all methods compared with analyses of the brews performed in laboratory. Sensory analyses are on course in order to evaluate grid acceptability for each method and combine higher CGA and CGL contents with higher acceptability.

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Reference:

Farah et al, 2005. *J. Agric. Food Chem.* **53**, 1505-1513

**PC454**

**SURVEY ON OTA CONTENT IN « CONVENTIONAL » AND  
« GRANO DE ORO » COFFEE TYPES FROM VENEZUELA**

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Ochratoxin A (OTA) is a secondary metabolite produced by various filamentous fungi, is deemed to have nephrotoxic, immunotoxic, teratogenic and carcinogenic effects. In tropical zones, OTA is mainly produced on coffee beans by three *Aspergillus* species: *A. carbonarius*, *A. niger* section Nigri and *A. ochraceus* section Circumdati. In temperate zones *Penicillium verrucosum* and *P. nordicum* are known to synthesize OTA in food commodities.

The OTA content in coffee was shown to be closely linked to harvesting conditions, post-harvest processing conditions, storage and transportation conditions.

The incidence of OTA was studied on 80 coffee samples from Sucre state in Venezuela. The objective of this study is to verify the impact of two types of wet processing on coffee produced in this area: the conventional coffee, prepared with a traditional wet method and the “grano de oro” coffee, prepared with high quality wet method.

**PC455**
**CHEMICAL CHARACTERIZATION OF ARABICA COFFEE ( COFFEA ARABICA L.) BEVERAGE PATTERNS OF COOPERATIVES FROM SOUTH OF MINAS GERAIS -BRAZIL.**

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The coffee quality is directly related to various constituents physical, physical-chemical and chemical that are responsible for the aspect of roasted grain, flavor and aroma of drinks, and among these compounds, we highlight the constituents volatile, phenolics (chlorogenic acid), fatty acids, proteins and some enzymes whose presence, levels and activities provide to the coffee a unique flavor and aroma.

This work aimed to characterize chemically green grains of arabic coffee ( *Coffea arabica* L.), previously classified with relationship to the five beverage patterns (strictly soft, soft, hard, riada and riox) coming of two cooperatives of the South of Minas Gerais. To characterize the coffee were analyzed for chemical composition, chlorogenic acids, caffeine and trigonelline using HPLC, all conducted at the Federal University of Lavras.

The drinks (soft, hard and riox) showed smaller moisture tenors did not significant difference from each other (Table 1), high levels of humidity favor the further development of microorganisms. The results indicated that the hard drink with higher contents of lipids and protein. It was found that the fiber did not differ as to the standard soft drinks and analyzed for ash drink riada showed a higher content.

Table 1. Proximate composition of coffee (*Coffea arabica* L.)

Coffee ( <i>Coffea arabica</i> L.)	Strictly soft	Soft	Hard	Riada	Riox
Moisture	6,260b	5,438a	5,467a	5,508a	6,188b
Lipids	10,318c	10,616d	10,809e	9,953a	10,052b
Fiber	13,735a	14,995a	16,189a	14,823a	16,359a
Ash	3,830c	3,790b	4,092d	4,127e	3,570a
Protein	14,592c	14,751d	15,284e	14,209b	13,577a

\*Means followed by same letter in the line did not differ by Tukey test ( $p < 0.05$ ).

The drink riada presented larger tenors of caffeine (2,12 %), trigonelline (1,90 %) and chlorogenic acids (5,58 %) compared to the in drink patterns studied. In coffee, trigonelline is an slightly bitter alkaloid and important precursor for various flavor compounds.

PC456

## CHARACTERIZATION OF FIBERMODIFIED SPENT COFFEE GROUNDS FOR TREATMENT WITH ALKALINE HYDROGEN PEROXIDE

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The spent coffee grounds, is an insoluble material resulting from the industrial process of soluble coffee consisting mainly of structural cellular wall polysaccharides and is used to generate steam, having no other technological application in the industry, being burned in boilers to generate steam, or transferred for agriculture, which uses it as organic fertilizer.

This work aimed to modify spent coffee grounds with alkaline hydrogen peroxide.

The objective of this study was to modify the hydration properties of spent coffee grounds and characterize it. The spent coffee grounds was treated with 1% alkaline hydrogen peroxide for 5 hours at 30 ° C. To characterize the modified coffee grounds were analyzed for chemical composition, dietary fiber, fiber fractions (cellulose, hemicellulose, lignin) and water retention capacity, all conducted at the Vegetable Products Laboratory, Department of Food Science, Federal University of Lavras.

The modification of the coffee grounds fiber caused a 75% increase in water retention capacity compared to untreated coffee grounds. This treatment allowed obtaining a product with high protein content (13.16%), fat (17.89%) and total dietary fiber (64.19%), which is composed of soluble dietary fiber (0.58%) and insoluble dietary fiber (63.61%). The fiber fraction was composed of cellulose (45.46%), hemicellulose (2.61%) and lignin (21.48%). Therefore, by its chemical composition characteristics, the modified coffee grounds may be used as a source of fibers for the manufacture of products with functional appeal.

PC457

## STABLE ISOTOPE FORENSICS FOR GEOGRAPHICAL INDICATION OF ETHIOPIAN SPECIALTY COFFEES

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Ethiopia is a primary centre of origin and genetic diversity for Arabica coffee and has several 'specialty coffee' production regions. Geographical Indication (GI) of Ethiopian specialty coffees may represent an important opportunity to add value to its economy and society. To do so, traceability of geographic origin is primordial. We tested whether multi-element and multi-isotope fingerprinting of green coffee beans could allow discriminating coffee producing regions and farms.

Therefore we have selected 15 coffee producing farms representing the following zones in South West (Bench Maji, Godere, Sheka, Jimma, Illu Ababora), West (W. Welega, Q. Welega), South (Gedeo), North West (W. Gojam) and East (W. Hararghe and E. Hararghe) Ethiopia. Coffee cherries were obtained by hand picking at peak maturity in the 2010-2011 growing season following a multistage purposive random sampling method in a nested design. We collected in total 141 different green coffee bean samples considering altitude, shading and processing methods where possible. All coffee samples were treated separately and green beans ground for analyses. Multi-element (31: K, Mg, Ca, B, Na, Al, Sc, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Rb, Sr, Mo, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Pb, Bi, Th) analyses was conducted using ICP-MS, strontium isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) were determined with MC-ICP-MS, boron isotope ratios ( $d^{11}\text{B}$ ) was determined using SF-ICP-MS, nitrogen ( $d^{15}\text{N}$ ) and carbon isotope ratios ( $d^{13}\text{C}$ ) were analyzed with EA-IRMS, and oxygen isotope ratios ( $d^{18}\text{O}$ ) were determined by HT-IRMS.

The majority of the element concentrations and stable isotope ratios were significantly different among coffee regions and farms very likely due to interactions between the coffee plant and local climate, soil type and land management. The West and South region could be separated based on its low  $d^{15}\text{N}$  (2.1-3.4‰) and low  $d^{18}\text{O}$  (32.0-33.6‰) compared to all other regions. West and South could be further separated from each other via different  $d^{11}\text{B}$  values; 27.0 vs. 33.8‰, respectively. The East and North West region could be separated from all other regions based on high  $d^{18}\text{O}$  (35.2-39.2‰) and high  $d^{15}\text{N}$  (4.9-5.6‰). East and North West could be separated from each other via  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios; 0.7069 vs. 0.7084, respectively. Finally, the South West region was discriminated from all other regions via a combination of high  $d^{15}\text{N}$  (4.8‰) and low  $d^{18}\text{O}$  (31.6‰) values.

Accordingly, the obtained analytical fingerprinting is highly suitable to discriminate between different Ethiopian coffee regions. Multivariate statistical analyses will be presented graphically showing the discriminating potential of the complete analytical fingerprint for Geographical Indication of Ethiopian coffee regions and farms.

**PC458**

## OPTIMISATION OF CHROMATOGRAPHIC TECHNIQUES FOR THE ISOLATION AND ANALYSIS OF VOLATILE AROMATIC COMPOUNDS IN COMMERCIAL COFFEE SAMPLES

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Methods used for the extraction and concentration of the volatile compounds found in coffee vary across studies. The extraction method chosen for coffee volatiles in this project was the simultaneous distillation extraction (SDE) method. The SDE was the most suited to produce a representative extraction of the coffee sample. The concentration of the extract was compared using two methods: nitrogen gas evaporation and Kuderna-Danish concentration. It was found that the nitrogen gas evaporation could concentrate the extract more efficiently and to a smaller volume. Tetradecane was the internal standard used for quantitation of the aroma compounds.

The extracted volatiles were separated and identified using an optimised Gas Chromatography Mass Spectrometry (GC-MS) method.

The extraction method was used to characterise the aroma profiles from commercial samples of coffee various origins: Zentveld's *Ernesto Roast* (Australia, standard); *Highlands Coffee* (Vietnam); *Kapal Api* (Indonesia); *Suan Ya Luang* (Thailand); *Cafe Canecão* (Brazil); *Cafe Aguila Roja* (Colombia); *Kopi Luwak* (Indonesia); *Loa Sinuak* (Laoi); and *Goroka Coffee* (Papua New Guinea).

Important character-impact aromatic compounds were found in all samples. These were furans, pyrazines, pyridines, pyrroles, phenols, esters, and sulphur compounds. There was a similarity in the profile of furans, pyrazines and pyridines across the samples. In contrast, sulphur containing compounds varied more, and have more of an influence on the perceived aroma of the coffee.

The sulphur compounds, present in each of the coffees although at much lower concentration, are more powerful and in effect have a potential to have a greater influence on aromatic character. It is possible that the presence of sulphur in the volatiles strengthens the character impression of the overall aroma and strikes a familiar scent. The ability of sulphur compounds to have an 'odour addition', or synergism to other aromatic compounds, could indicate that the particular concentration and mix of the sulphur compounds in a coffee, will distinctly define its aroma.

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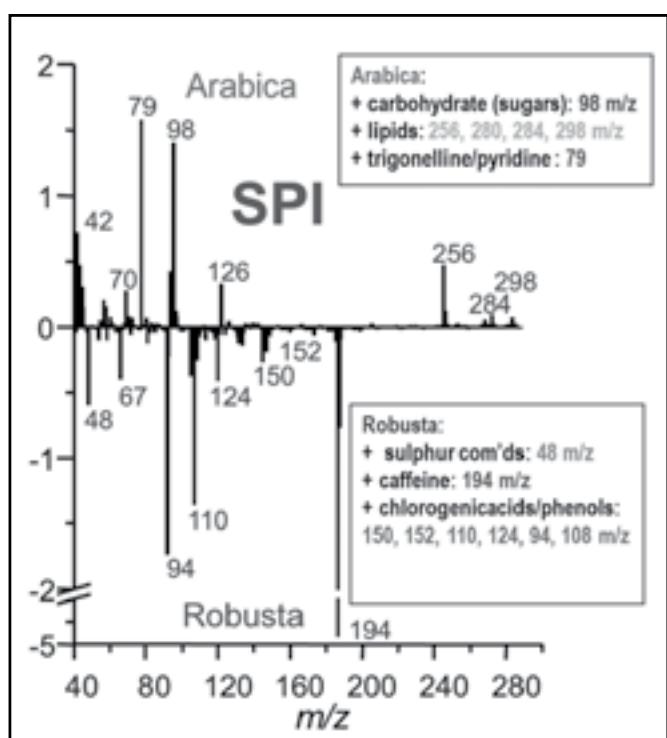
**PC459**
**DIFFERENTIATION OF THE ROBUSTA AND ARABICA VARIETIES BY  
ON-LINE ANALYSIS OF THE CHEMICAL SIGNATURE IN THE ROASTING-  
GAS INSIDE OF INDIVIDUAL COFFEE BEANS DURING ROASTING BY  
MICROPROBE-SAMPLING PHOTO-IONISATION MASS SPECTROMETRY**


Figure 1: Difference SPI-mass spectrum of the roasting gases of the Robusta and Arabica varieties measured inside of the respective beans.

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Single-Photon Ionization and Resonance-Enhanced MultiPhoton Ionization Time-Of-Flight Mass Spectrometry (SPI-/REMPI-TOFMS) were applied for studying the coffee and cocoa roasting process. Both techniques are very sensitive. While REMPI is particularly sensitive and selective for fast on-line detection of aromatic molecules, SPI allows the acquisition of overview mass spectra consisting of all organic species. However, REMPI and SPI are both soft ionization methods, allowing the direct recording of the molecular ion profiles. REMPI-and SPI-TOFMS has been applied e.g. for on-line trace measurements aromatic hydrocarbons in industrial flue gases [1], for puff resolved monitoring of cigarette smoke

[2] and for on-line recording of the coffee roasting process [3]. In this work a SPI-/REMPI-TOFMS system was used for studying the formation of roasting gases within individual coffee beans. For this purpose the tip of a special microprobe sampling device was inserted in a small drilled hole in the green bean. Subsequently the so prepared beans were roasted at 200 °C and the evolved gases from the interior of the bean were analyzed by the photo ionization mass spectrometer. In Figure 1 a difference SPI mass spectrum of the internal roast gases sampled from Arabica and Robusta varieties respectively is shown. The difference mass spectrum is based on three added SPI-mass spectra of each variety, averaged over the whole roasting process. The varieties can be clearly differentiated and sound discriminating compounds such as phenols, pyridin, lipids, caffeine and kahweol are detected. In addition to difference spectra also multivariate statistics was used to identify volatile markers for roasting degree and coffee variety.

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## PC460

### METABOLOMIC ANALYSIS OF COFFEE CULTIVARS IN HAWAII

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Cup-testing is widely used to evaluate bean quality characters. Chemical analysis of beans such as sugar and acids has been conducted, while no clear correlation was found with beverage quality. Metabolic profiling techniques can provide information on the relationship between the metabolome and factors including beverage quality. In the past metabolomic study has been conducted using limited number of chemicals and coffee samples without information of the cultivars and origins. It is important to verify the final products of metabolisms in relation to beverage quality of coffee cultivars.

We studied on correlation between chemical component information in *Coffea arabica* cultivars using LC/MS analysis. Cherries were harvested from 8 cultivars of arabica coffee, grown at HARC, Kunia field Hawaii. A total of 2000-4000 chemical components were obtained in green beans processed from these cherries. By PCA Score plot of the chemical components of the total samples, we separated genotypes clearly. The results of S-Plot enabled extraction of characteristic components for cultivars. We expect that beverage quality correlates to both genotypes and chemical components- metabolomics using this method.

Application of a metabolomic approach to evaluate beverage quality of coffee may be useful to study various metabolic pathways and gene expressions in the pathways.

PC461

THE IMPACT OF COFFEE SOLIDS ON THE HEADSPACE  
AVAILABILITY OF VOLATILE AROMA COMPOUNDS**FISK, Ian\*#, YI, Liu\*, LINFORTH, Robert\*, SOUKOULIS, Christos\***

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As one of the primary quality factors of soluble coffee is its aroma there have been many studies over previous years investigating the aroma's molecular composition [1], extraction kinetics [2], generation reactions during roasting, stability kinetics during ageing [3], and the impact of the addition of milk on aroma availability, but there are only a small number of reports on the impact of the soluble components of coffee on the availability of coffee aroma after hydration [4-6].

In this study, an aqueous coffee solids concentrate was generated by passing coffee liquor through an amberlite XAD-4 columns three times to de-aromatise the matrix leaving concentrated slurries enriched in arabinogalactan, galactomannan and melanoidins.

Key aroma compounds were analysed within the original coffee brew by GC-O, of which five volatile compounds were chosen to represent the range of aroma compounds present, these varied in their hydrophobicity and volatility and were added back to the de-aromatised coffee base at standard UK consumption levels.

The concentration of volatile compounds in the headspace was analysed by APci-MS and the de-aromatised coffee base significantly depressed the availability of the aroma compounds in the gas phase, this varied by compound, indicating interactions between the aroma compound and the base.

In the example of 2,3 butanedione, there was a 60% reduction in headspace availability with the addition of de-aromatised coffee solids, and a 30% reduction for guaiacol which leads one to the hypothesis that coffee solids impact on, not only the headspace availability, but also the ratio of available aromas, and potentially the perceived aroma will therefore differ in both intensity and balance depending on the addition of different solids contents.

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## PH 300

EFFECTS OF OXIDATIVE COMPONENT-REDUCED COFFEE  
CONTAINING HIGHER LEVELS OF CHLOROGENIC ACIDS ON BLOOD  
PRESSURE, BODY FAT, AND ENERGY METABOLISM IN HUMANS.

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Coffee products generally contain an abundance of chlorogenic acid (CGA), which is a well-known anti-oxidative agent. Animal studies revealed that CGA reduces blood pressure, and hydroxyhydroquinone (HHQ) inhibits this effect.

HHQ, pyrogallol, and hydroquinone, all of which generate reactive oxygen species, are produced as an oxidative component by green coffee beans during the roasting process. These oxidative components are thought to inhibit the beneficial effects of CGA. Therefore, an oxidative component-reduced (OC-R) coffee was developed by removing most of the roasting process-derived oxidative components while maintaining a large amount of CGA. The effects on blood pressure, body fat, and energy metabolism were analyzed in clinical trials in humans.

Studies A, B: The protective effect of OC-R coffee against hypertension was evaluated in 41 high-normotensive and 59 mildly hypertensive adult men and women in a double-blind, randomized placebo-controlled parallel study. The subjects were randomly assigned to either the active group (Active beverage, OC-R coffee: CGA, 299 mg/184 mL; HHQ, 0.05 mg/184 mL) or placebo group (Placebo beverage, both components-reduced coffee: CGA, 0 mg/184 mL; HHQ, 0.02 mg/184 mL), and consumed one serving (184mL/can) each day for 12 weeks. Systolic blood pressure was significantly lower in the active group ( $n=49$ ) than in the placebo group ( $n=51$ ) based on a linear mixed-model repeated-measures analysis of covariance (group effect,  $p<0.05$ ). This effect was supported by the findings of a similar study (Study B) using a coffee product with or without the oxidative component. Systolic blood pressure was significantly lower in the active group, which ingested coffee containing only CGA ( $n=51$ ), than in the control group ( $n=47$ ), which ingested coffee containing both CGA and HHQ (group effect,  $p<0.05$ ).

Study C: The preventive effect of OC-R coffee against body fat accumulation was evaluated in 109 obese men and women in a double-blind, randomized placebo-controlled parallel study using the same active and placebo beverages as used in Study A and a similar protocol. Visceral fat area, body weight, and waist circumference were significantly lower in the active group ( $n=53$ ) than in the placebo group ( $n=56$ ) based on a repeated-measures analysis of variance (group-by-time interaction,  $p<0.05$ ).

Study D: To investigate the mechanism underlying the anti-obesity effect of CGA, energy metabolism after ingestion of OC-R was evaluated using an indirect calorie meter in a double-blind placebo-controlled study with a crossover design. Seven healthy men randomly consumed either the active beverage (359 mg CGA in 185 g beverage) or placebo beverage (0 mg CGA in 185 g beverage) for 1 week (185 g per day). Postprandial oxygen consumption and fat utilization were significantly enhanced in the active group compared with the placebo group (paired T test,  $p<0.05$ ).

In conclusion, the consumption of coffee containing high amounts of CGA helps to protect against hypertension and obesity, especially when the oxidative components are removed. A potential mechanism for the anti-obesity effect is enhanced fat utilization as energy.

## PH 302

### HEALTH AND COFFEE UPDATE 2012

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**Introduction:** The world coffee market is preoccupied with the beneficial health aspects of coffee. The author is both a practicing physician and a roaster-retailer. The purpose of this review is to use these perspectives to present an updated outline of our current knowledge of health matters as they may affect public opinion of our industry.

**Methods:** Forty years as a practicing physician and twenty years as a roaster-retailer were reviewed to identify a meaningful experience of trends in the specialty coffee market related to coffee. The bottom line was that the world coffee market is being influenced by the public's increasing awareness that coffee in moderation is part of a healthy lifestyle.

**Results:** Four agents found in coffee affect health: caffeine, diterpenes, chlorogenic acids, and niacin. Caffeine in the brain acts by a variety of chemical and electrical mechanisms. Relevant effects include control of Parkinson's disease, cognition, performance, and perhaps migraine. In the liver, acute caffeine administration impairs glucose tolerance, but increases insulin sensitivity, and promotes energy metabolism. Chronically, coffee administration improves glucose tolerance. Caffeine is also a diuretic and a selective smooth muscle relaxant. Whereas, there is nothing to unsubstantiate the use of caffeinated coffee in moderation, there remains a significant and growing demand for quality, whole bean, decaffeinated coffee. The diterpenes, cafestol and kahweol, are associated with increased enzymes which may contribute to increases in cholesterol. They are absent in coffee brewed with filtration. The adverse effect on cholesterol is marginal but sufficient to contribute to the increasing demand for filtration brewing in preference to boiled or steam extraction techniques. Chlorogenic acid and cinnamic acid are polyphenol antioxidants. Resveratrol, another antioxidant, is of intense interest to the lay public even though there are few reports validating its clinical relevance. Finally, one of four micronutrients may be important. Niacin in conventional coffee usage may modify lipids and thus contribute to the control of atherosclerosis. It also corrects pellagra. The other three, magnesium, potassium, and vitamin E, are only 0.1-5% of recommended daily requirements.

**Discussion:** From the health standpoint, coffee consumption contributes to the control of type 2 diabetes mellitus (metabolic syndrome), Parkinson's disease, liver disease, and perhaps depression, suicide risk, dementia, migraine, and respiratory function. Moderate coffee intake, below 300 mg per day, or 3 mg/kg in children, will not increase the risk for stroke, arrhythmia, hypertension, cancer, complications of pregnancy, or kidney stones. Finally, coffee in excess of three cups per day may be associated with a variety of adverse side effects. Hence, quality over quantity is an emerging market consideration for heavy coffee drinkers. From the roaster-retailer's standpoint, these changes in public opinion are increasing the demand for specialty coffee. Specifically, they are focusing the public's attention on brewing techniques, caffeine content and quality.

**Conclusion:** These results explain why coffee is becoming a positive factor in the world coffee market. From the public's perspective, coffee in moderation is regarded as generally beneficial and, with minor qualifications, seldom harmful. As a result, the demand for specialty coffee is increasing.

**PH 303**

**DOES COFFEE PREVENT PROSTATE CANCER?**

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**Introduction:** Prostate cancer preoccupies coffee drinkers. Approximately, one in 9 coffee drinkers has prostate cancer. For many, their prostate cancer might never have been discovered without screening. For others, their prostate cancer is lethal. Preventive measures include control of weight and cholesterol. Benefit from selenium and vitamin E has not been substantiated. Active surveillance rather than conventional definitive therapy is now currently recommended for low risk individuals because their disease is likely to be nonlethal. It is only the minority of high risk individuals who warrant aggressive prophylaxis and treatment. High risk individuals have poorly differentiated histology, advancing tumor size and/or spread, an escalating prostate-specific antigen and/or a risky genome.

**Methods:** The Health Professionals Follow-up Study is a prospective cohort of 51,529 male health professionals in the United States aged 40-75 at baseline in 1986. Kathryn M. Wilson, ScD, Harvard School of Health, assessed the database and was able to identify a subset of 642 high risk individuals.

**Results:** The strongest associations were for lethal and advanced prostate cancer. The age related incidence rates of lethal prostate cancer for heavy coffee drinkers and non-coffee drinkers were 34 and 79 per 100,000 person-years, respectively. (P=.03 for lethal cancer and P=.004 for advanced cancer). Results were similar for drinkers of caffeinated or decaffeinated coffee.

**Discussion:** The United States Preventive Services Task Force report on prostate cancer screening has underlined the large proportion of prostate cancer that is low risk, nonlethal and probably would not have been identified in the absence of prostate cancer screening. It is this subset that probably masked previous attempts to identify a positive role for coffee in reducing the risk of clinical, high risk and lethal disease,

**Conclusions:** Heretofore, coffee has not been shown to decrease the risk of prostate cancer. With the advent of an understanding of the large cohort of low risk, nonlethal disease, there is a possibility that coffee with or without caffeine may prevent prostate cancer as reflected by the reduction of high risk, lethal disease in the coffee drinking cohort. Confirmatory population studies should be pursued. Standard murine models for high risk prostate cancer are available and should also be utilized to address this issue.

## PH 304

KINETIC ANALYSIS ON THE INHIBITION OF PORCINE PANCREAS  
D-AMYLASE BY CHLOROGENIC ACIDS FROM GREEN COFFEE  
BEANS AND CINNAMIC ACID DERIVATIVES.**NARITA, Yusaku\*, \*\*, INOUYE, Kuniyo\***

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Coffee is one of the most consumed drinks in the world, and a major source of polyphenols, in particular, chlorogenic acids (CGAs), in human diet. The nine kinds of CGAs account for 80% of the total CGA content in green coffee beans. They consist of three subgroups of caffeoylquinic acids (CQAs), feruloylquinic acids (FQAs), and dicaffeoylquinic acids (diCQAs).  $\alpha$ -Amylase inhibitors are effective to the prevention of diabetes and obesity in order to control elevation of plasma blood glucose levels by delaying postprandial carbohydrate digestion and absorption.

We previously reported that the inhibitory effect of 5-CQA, and its components, caffeic acid (CA) and quinic acid (QA), on the porcine pancreas  $\alpha$ -amylase (PPA) isozymes, PPA-I and PPA-II, using *p*-nitrophenyl- $\alpha$ -D-maltoside as substrate at pH 6.9 and 30°C [1, 2]. The inhibition potencies of the respective inhibitors against both isozymes were almost the same and in the order of 5-CQA > CA > QA. The inhibition models of 5-CQA and CA on PPA-I and PPA-II were investigated by kinetic analysis, and it was indicated that 5-CQA and CA showed mixed-type inhibition with  $K_i > K'_i$  (the inhibitor constants for free enzyme and enzyme-substrate complex, respectively) against both PPA-I and PPA-II. The binding of PPA-I or PPA-II with 5-CQA or CA are all exothermic and enthalpy-driven from thermodynamic analyses. In the PPA inhibition of 5-CQA and its components (CA and QA), no difference was observed in the inhibition against the isozymes. Although the inhibition of 5-CQA against PPA has been considerably revealed, the effects by other CGAs contained in green coffee beans are remained to be elucidated.

In this study, based on our previous report, the inhibition effects of eight kinds of CGAs (3-CQA, 4-CQA, 3-FQA, 4-FQA, 5-FQA, 3,4-diCQA, 3,5-diCQA and 4,5-diCQA) and eight cinnamate derivatives [cinnamic acid (CiA), *m*-methoxycinnamic acid (*m*-MCiA), *p*-methoxycinnamic acid (*p*-MCiA), ferulic acid (FA), isoferulic acid (IFA), *p*-coumaric acid (*p*-CoA), *m*-coumaric acid (*m*-CoA), and dihydro caffeic acid (DHCA)] against PPA-I and the structure-function relationship were evaluated [3]. 3-CQA, 4-CQA, 5-CQA, 3-FQA, 4-FQA, 5-FQA, 3,5-diCQA, FA, IFA, *m*-CoA, *p*-CoA, *m*-MCiA, *p*-MCiA, and CiA show mixed-type inhibition with  $K_i > K'_i$ , suggesting that the inhibitors bind to the ES complex stronger than to the free enzyme E. In contrast, 3,4-diCQA and 4,5-diCQA show mixed-type inhibition with  $K_i < K'_i$ , suggesting that these inhibitors bind to E stronger than to ES.

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**PH 305**
**EFFECT OF COFFEE DECAFFEINATION ON THE LIPID PEROXIDATION IN HYPERLIPIDEMIC RATS**

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Decaffeination is known to induce changes in coffee's bioactive compounds. This study aimed to evaluate the effect of coffee decaffeination, in arabica and robusta species, on the lipid peroxidation in hyperlipidemic rats liver. Filter coffee was used, from arabica (A), decaffeinated arabica (DA), robusta (R), and decaffeinated robusta (DR) coffees. Decaffeination was performed with methylene chloride. Rats (n=30) were assigned into six groups, with a negative (C-) and positive control (C+), and one group for each coffee brew type. Rats were fed *ad libitum* on a hypercholesterolemic diet (0.5% cholesterol and 0.25% cholic acid), except for C- (normal diet), receiving 7.2 mL/kg/day of brew by oral gavage, for 42 days. Malondialdehyde (MDA) is considered a presumptive biomarker for lipid peroxidation in living organisms. MDA was estimated by quantification of the thiobarbituric acid reactive species (TBARS) by HPLC on the liver homogenates. Protein was estimated by the Bradford assay.

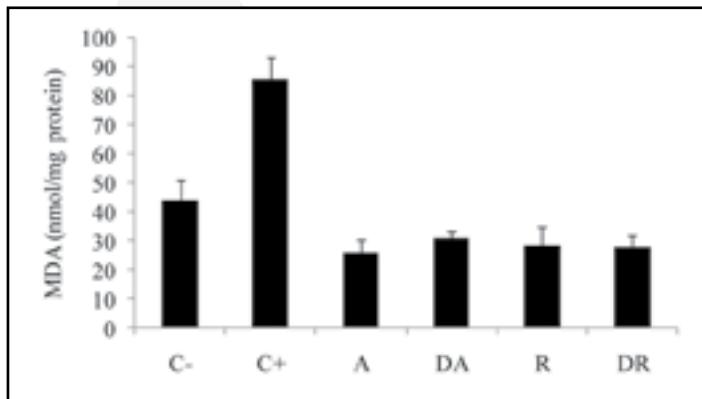


Figure 1 - MDA levels in rats liver (nmol/mg protein).  
(Different letters indicate significant differences by the Scott-Knott test at 5% probability).

The C+ group showed higher levels of MDA than the C- group indicating that the diet induced lipid peroxidation in rats liver. All groups treated with coffee brews showed a significant reduction in hepatic MDA content when compared to the C+ group. The concentration of MDA in the groups treated with the coffee brews was significantly lower than the values in the C- group, suggesting that the antioxidant compounds in coffee are able to inhibit lipid peroxidation. As regards to the effect of coffee decaffeination, no significant differences were observed, as well as between species.

These results suggest that the ingestion of coffee brews might protect the liver cells from oxidative stress damage, being this observation independent of coffee species and decaffeination process.

Acknowledgment: FAPEMIG, CAPES and CNPq supported this work.

PH 306

DRINK OF COFFEE - *COFFEA AR BICA L.* CONSUMPTION  
EFFECT ON PLATELETS OF RATS

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In the last years, countless evidences have indicated that oxidative stress is an important risk factor for cardiovascular disease. The action of free radicals is potentiator in the formation of atheromatous plaque due to changes of vascular endothelium with oxidative stress, exacerbating the leukocyte-platelet adhesion and consequently the platelet aggregation in the endothelial wall. In this way it is recommended the use of antioxidants as inactivating agents free radicals in order to inhibit the plaque formation. Epidemiological studies have relate the consumption of drinking of coffee and the cardiovascular risk, suggesting that moderate drinking of coffee may be beneficial to health. Coffee is the major source of chorogenic acid of the diet, with antioxidative action. The objective of this study was to evaluate the acute consumption of coffee integral on platelet aggregation in rats. The study of 20 male Wistar rats, weighing  $320\text{g} \pm 20\text{g}$ . The coffee drinks integral ( $7.2 \text{ mL/Kg-1}$ ) was administered daily by gavage to the animals for a period of 7 days. Control animals received water in the same dose. The platelet aggregation was tested front of the agent agonists Adenosine Diphosphate ( $1 \mu\text{M}$ ) in the Aggregometer Brand Qualiterm Dual Channel, the standard temperature of  $37^\circ\text{C}$ . In the control group achieved platelet aggregation was  $61.57 \pm 7.11$  in the group of animals that ingested the coffee beverage obtained platelet aggregation was  $62.3 \pm 10.33$ . The results indicate that acute consumption of coffee has no effect on platelet aggregation in rats. This is important for safe human consumption as the coffee drink is a drink consumed most throughout the world.

Acknowledgment: FAPEMIG, CAPES and CNPq supported this work.

**PH 307**

## **INFLUENCE OF PARTICLE SIZE ON THE EXTRACTION OF FREE BIOACTIVE AMINES FROM COFFEE**

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Coffee contains bioactive amines, which fulfill a number of important metabolic and physiological functions in living organisms. The polyamines spermine and spermidine play important roles in cell division, organogenesis, response to stress and inhibition of lipid oxidation. The biogenic amines histamine, tyramine, tryptamine, serotonin, putrescine and phenylethylamine are neuro- or vasoactive. Due to modern detection methods, the knowledge about amines and their role in health and disease are better understood. However, extraction of amines from complexes matrixes, such as coffee, still requires investigation to warrant quality of analytical results. The objective of this study was to evaluate the influence of the size of particles of green coffee beans on the extraction of free bioactive amines. Robusta coffee beans were subjected to grinding in two different mills - roller and hammer mills and classified by screening into sieves of 4, 8, 9, 20, 28, 32 and 60 meshes with openings of 4.75, 2.36, 2.00, 0.85, 0.60, 0.50, and 0.25 mm, respectively. 5% Trichloroacetic acid (TCA) was used for amines extraction and parameters like volume of acid required for analysis during extraction and the contents of free amines extracted from the samples were compared. Ten amines were separated and quantified by ion pair-HPLC, post-column derivatization with o-phthalaldehyde and fluorimetric detection at 340 nm excitation and 445 nm emission. The size of the particles affected significantly the volume of required for analysis. The volume of extract obtained with particle sizes smaller than 0.85 mm, was significantly lower compared to grains with particle sizes bigger than 0.85 mm. Among amines investigated, spermidine, spermine, putrescine, tyramine, serotonin, and phenylethylamine were found in the samples. The particle size of the grain affected significantly the recovery of amines during extraction. Larger particle sizes (4.75 mm to 2.36 mm) as well as provided low percentages of amine recovery (41% to 59%). Moreover, smaller particle sizes (0.25 mm) in spite of the larger superficial area, which facilitate contact, also gave low recovery of the amines (77 %). Intermediate particle sizes (2.00 mm to 0.50 mm) provided better recoveries (80% to 100%). Based on these results, the ideal particle size for amine extraction from green coffee beans is 2.00 to 0.85 mm, which is equivalent to sieves of 9-20 mesh.

Financial support: Fapemig, CNPq, Capes.

PH 308

ANTIMICROBIAL ACTIVITY OF CAFFEINE AND PROTOCATECHUIC ACID AGAINST *SALMONELLA TYPHIMURIUM* AT DIFFERENT PH AND EFFECTIVENESS IN A MILK MODEL SYSTEM**ALMEIDA, Ana Amélia P.\* , NUNAN, Elzíria A. \*\* , GLÓRIA, Maria Beatriz A.\*\***

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Foodborne illness has been of great concern to public health. Therefore, today, there is a need for natural antimicrobial agents to inhibit bacteria growth and to extend the shelf-life of foods. Many coffee compounds, such as caffeine and protocatechuic acid, have shown to possess antimicrobial activity in vitro, however, few studies investigated their effect on food systems. The objective of this study was to investigate the antibacterial effect of caffeine and protocatechuic acid in a milk model system at two pH values inoculated with *S. enterica* serovar Typhimurium, which is a highly invasive human pathogen. The milk model system (simulating acid dairy food) consisted of a suspension of non-fat dry milk (10%) containing 4.96 mg/mL of caffeine or 4.14 mg/mL of protocatechuic acid, both adjusted to pH 4.5 and 5.5 after the sterilization. The samples were inoculated with  $10^6$  cfu/mL of *S. Typhimurium* and incubated at  $25.0 \pm 1.0$  °C. The counts of viable cells of *S. Typhimurium* were taken at 24 h and at 7 days intervals up to 28 days. They were enumerated on nutritive agar incubated at  $36.5 \pm 1.0$  °C for 48 h. The inhibitory effect of caffeine in the model system was determined by the microtiter plate method described by United State Pharmacopeia and also by means of an atomic force microscope. The addition of caffeine or protocatechuic acid to the system significantly inhibited *S. Typhimurium* growth. The strongest inhibitory effect was observed at pH 4.5, providing 96% inhibitory effect for both compounds. Analysis of microscopic images indicated that both compounds affected the morphology of the cells. Protocatechuic acid altered the surface of the cells, providing a coarse and coccoidal aspect. Caffeine caused elongation of the cells and also a decrease in growth, possibly by interfering in the mechanism of cell division, mainly septum formation. Based on these results, it is likely that coffee extracts added to food products could afford protective effects against pathogenic microorganisms. Further research should be undertaken to elucidate the effectiveness of coffee extracts and residues from the coffee industry on the extension of the shelf life of food products.

Financial support: Fapemig, CNPq, Capes.

PH 309

## EFFECT OF COFFEE EXTRACTS ON INTRACELLULAR CALCIUM LEVEL IN LEVELS IN GLIAL CELLS

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Widely used antidepressant drugs such as fluoxetine exert additional blocking effects on voltage gated Ca<sup>+2</sup> channels. Differences in intracellular calcium levels may be involved in the release of monoamines, which play important role in the pathogenesis of depression<sup>1,2,3</sup>. Coffee is one of the most widely used beverages and is potentially beneficial to various psychiatric disorders, including depression and psychosis. In a recent study, it was suggested that caffeine intake was associated with a decreased risk of clinical depression<sup>4</sup>. Nevertheless, caffeine intake has been also reported to increase depressive symptoms in cross-sectional studies<sup>5,6,7</sup>. Therefore, the role of coffee in the promotion or prevention of depression is still unclear. In the present study, we examined the effect of coffee extracts with distinct chemical compositions, on intracellular calcium levels in glial cells, using ratiometric fura-2-based spectrofluorometric measuring. Glial cells were incubated for 2h with six coffee extracts at 0.01% (w/v), obtained from decaffeinated and non-decaffeinated green and roasted (light medium and dark roasting degrees) *C. canephora* beans. The regular green coffee extract, containing the highest levels of chlorogenic acids, and caffeine and trigonelline, among other compounds, increased intracellular calcium levels in glial cells after 2h incubation. This increase was significantly higher comparing to the effect of decaffeinated green coffee extract. Additionally, as roasting intensity increased, the effect was also weaker and results from dark roasted coffees were not different from control. Considering the thermostability of caffeine, our findings indicate that the association of caffeine with other compounds present in green coffee can promote differences in the intracellular levels of calcium and that the consumption of green coffee may be related to depressant or antidepressant effects. Further behavioral and *in vitro* studies with individual compounds are required to clarify these findings.

Financial support: Istanbul Bilim University (Turkey), FAPERJ (Brazil)

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**PH 310**

## **CONSUMER ACCEPTANCE THRESHOLD FOR IRON AND ZINC CONCENTRATIONS IN BREWS OBTAINED FROM FORTIFIED GROUND ROASTED COFFEE**

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An adequate intake of nutrients contributes to the normal growth, development and well being of the human organism, protecting individuals against the risk of diseases caused by nutritional deficiencies. However, micronutrients malnutrition is still observed worldwide, especially in developing countries. Of major concern is the prevalence of iron (Fe) and zinc (Zn) deficiency. Literature data indicate that the intake of these minerals in Brazil is below recommended intakes (DRI), despite the fortification of wheat flour as well as other commercial food products. Considering that coffee is the most popular food product in Brazil, being consumed by all social classes, we developed a fortified brewed coffee with addition of Zn and Fe, aiming to offer 30% of the daily recommended intake of these minerals for adults in a cup of brew. The goal of the present study was to evaluate the consumer acceptance threshold for iron and zinc concentrations in brews obtained from fortified ground roasted coffee. Iron bisglycine chelate and zinc bisglycine chelate were chosen for ground coffee (80% *C.arabica*, 20% *C.canephora*, medium roast, #65 SCAA, USA, fine grid) fortification after sensory tests previously carried out. Fe and Zn analyses in the ground coffee and in the brews were done by inductively coupled plasma atomic emission spectrometry (ICP OES). Acceptance test was used to determine acceptance threshold. Seventy one coffee consumers were invited to participate in the study and the only condition for participation was to consume at least one cup of black coffee per day. Six coffee samples containing increasing percentages of minerals were evaluated (0, 30%, 50%, 80%, 100% and 150% of adult DRI per 50mL cup). Brews at 10% (weight/volume) were prepared in electric coffee makers, served to participants in 50mL porcelain cups coded with three digit numbers at  $68 \pm 2$  °C, in individual computerized sensory booths, following a balanced presentation order. Participants were allowed to choose to sweeten (using sugar or artificial sweetener) or not their brews, according to their habits. Nine-point hedonic scales were used to evaluate the brews acceptability. Statistical analyzes were performed using the program XLSTAT® version 2010.3.01 (Addinsoft). To evaluate the percentage of minerals extraction from the ground coffee into the brew, ANOVA was used, followed by Tukey test, with 95% significance level. Acceptance data were also treated by ANOVA followed by Fischer (LSD) and test for comparison of means. The percentage of mineral extraction from fortified coffees in electric coffee maker was, on average, 95.3% and 48.5% for Fe and Zn, respectively. Sensory analysis, taking into account the percentage of extraction, showed that fortification up to the level of 80% of DRI (11.2 mg and 12.0 mg per 100 g coffee for Fe and Zn, respectively) was well accepted by consumers. Thus, roasted and ground coffee appears to be potentially suitable food vehicle for the fortification with Fe and Zn. However, the bioavailability of these minerals when added to ground roasted coffee matrix should also be considered.

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PH 311

EFFECT OF COFFEA CANEPHORA AQUEOUS EXTRACT  
ON EX VIVO ORAL BIOFILMS: A CASE STUDY

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The ex vivo antimicrobial effect of brewed coffee was tested on oral biofilms. For this, unsweetened and sweetened light-roasted *Coffea canephora* brews were used in biofilms formed by non-stimulated saliva from three volunteers. Saliva from each healthy donor was placed on 0.22 mm membrane disks positioned over plates containing culture medium (BHI-S, Brain Heart Infusion medium, supplemented with hemin, menadione and yeast extract). The system was incubated anaerobically for 48h at 37°C. After the biofilm growth, disks were collected and separately placed in tubes for 30 min with 2 mL of each of the following substances: (i) coffee aqueous extract at 20% (w/v); (ii) coffee aqueous extract at 20% with 10 % sucrose; (iii) Milli-Q water with sucrose (10%), (iv) aqueous solution of chlorhexidine (0.05%) – positive control; (v) plain Milli-Q water – negative control. This procedure was performed in duplicate. After the biofilm extraction, serial dilutions ( $10^{-1}$  to  $10^{-8}$ ) were performed, in triplicate, to enumerate viable cells. Plates were incubated anaerobically for 48 h at 37°C and CFU/mL was counted. The activity of the coffee extracts and sucrose solution on microbial biofilms was estimated by comparing the microbial population collected from the biofilms placed in the controls tubes and the microbial population collected from the biofilms placed in coffee extracts test tubes. The normal distribution of the errors was evaluated by Shapiro-Wilk's test for all response variables. The difference between the applied treatments was evaluated through Kruskal-Wallis test, followed by Mann Whitney for comparisons of substances two-by-two. Results were considered significant when  $p<0.05$ . Chlorexine solution reduced the average microbial population in the biofilms by 32%, while unsweetened and sweetened brews reduced the counts by 15.2% and 12.4%, respectively, with no statistical difference among them. No difference was observed between plain water treatment (no reduction in microbial count) and sucrose solution (reduction by 5%). Additional tests revealed that only sucrose concentrations below 5% increased microbial counts. The authors believe that in the present *in vitro* conditions, the high levels of sucrose provoked a drop in microorganisms osmotic tolerance, decreasing their viability. Considering that coffee is a natural ingredient that may be obtained in large quantities and at low cost, it may be beneficial as an anticariogenic ingredient due to its bioactive ingredients such as phenolic compounds, caffeine and trigonelline.

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PH312

## LC-MS(n) CARACTERIZATION OF ANTIOXIDANT COMPOUNDS IN COFFEE FRUITS AND THEIR EXTRACT ANTIRADICAL ACTIVITY

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Whole freeze dried and air dried coffee fruit samples of Arabica and Robusta from different countries of origin were analyzed by LC-MS(n) and HPLC for their major and minor bioactive compounds including chlorogenic acids (CGA), caffeine, proanthocyanidins, flavonols, trigonelline, etc. Antioxidant capacity and antiradical activities *in vivo* have been studied as well.

Quantification of hydroxycinnamic compounds was by comparison to an authentic standard of 5-O-caffeoylequinic acid, range 5 to 750 ng at 325 nm and caffeine at 275 nm in the range 5 to 750 ng. 5-O-Caffeoylquinic acid was the main chlorogenic acid present in all samples of coffee fruits, representing between 37 to 69% of the total chlorogenic acid content. Specific chlorogenic acids, including 3-O-caffeoylequinic acid lactone, 4-O-caffeoylequinic acid lactone, the putative methyl-5-caffeoylequinic acid and dicaffeoylquinic acid lactone, were detected in the coffee fruit extract with 40% of total chlorogenic acids.

Quantification of minor phenolic compounds was by exact mass measurements of calibration standards over the range of 0.5 to 50 ng using (-)-epicatechin for flavan-3-ol monomers and procyanidin B2 for dimer and trimer flavan-3-ols. Another class of compound, flavonols, was also detected. The first two of the four flavonols, was tentatively identified as quercetin-3-rutinoside based on MS-MS and exact mass. Quercetin-3-glucoside and quercetin-3-rutinoside were quantified as quercetin-3-glucoside equivalents.

The contents of trigonelline and caffeine in coffee fruits samples has been determined by HPLC and quantified by UV absorbance.

The ability of the samples to scavenge peroxy radicals (ORAC), hydroxyl radicals (HORAC), peroxynitrite (NORAC), superoxide anions (SORAC) and singlet oxygen (SOAC) was assessed.

Antiradical activity of PRP has been studied *in clinico* on two healthy subjects. Antiradical activity as followed after single dose administration at time-points T0, T60, T120 and T180. Chlorogenic and gallic acids are used for model study of antiradical and pro-radical activities in blood serum samples collected from non treated subjects. Different method have been used for measurements of free radicals concentration - fluorescence detection (FD), electrochemical detection with biosensors (EBS), and electron spin resonance spectroscopy (ESR) methods.

The collected data from *ex vivo* and *in clinico* experimentation will be presented.

PP 500

## PHYSICO-CHEMICAL CHARACTERIZATION OF THE WASTE PRODUCED BY MECHANICAL PULPING OF ROBUSTA COFFEE

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In coffee producing countries, waste and by-products of this chain are a major source of contamination and a serious environmental problem. Therefore, since the middle of last century have been striving to develop methods to use them as raw material for the production of feed, beverages, vinegar, biogas, caffeine, pectin, pectin enzymes, protein and organic fertilizer. In addition, by-products used as ingredients for other sectors have a source of income for the coffee production chain with high added value. Specifically in the case of coffee pulp or mucilage, there are studies that show results of the chemical composition of pulp that indicate its use as an ingredient for the food and drinks. In the case of Robusta coffee, where there is mechanical pulping, there is a substantial amount of waste produced. The use of products such as the pulp of coffee cherries brings both environmental and economic advantages since it is an alternative to add value to the productive chain of coffee. However, for the application of slurry in the food and drinks you need a careful study of the intrinsic characteristics of the product. In this context studied was the byproduct of the pulping waste of Robusta coffee. At this stage of the research studies have been conducted on their physico-chemical composition, as well as preliminary studies of income and technology industrialization of waste. Therefore three samples were initially assessed for this stage of the research: 1. Coffee residue extracted into peeler (pulping) with traditional mechanical addition of water, called the "pulp"; 2. Residue extracted into aqueous coffee peeler (pulping) and subsequent mechanical extraction kettle and washed worm, called the "aqueous extract"; 3. Residue retained on the screen pulper worm called "peel residue finisher". The three treatments described above were assessed for two clones of Robusta coffee from the Genebank of the Agronomic Institute of Campinas selected (67-9 and 69-1). The physical-chemical evaluations conducted for the six samples were: Soluble solids content in the samples, pH, instrumental color, moisture, total solids, total polyphenol content, total dietary fiber, total tannins, sugars by HPLC, total lipids, trigonelline, caffeine. The results were analyzed according to ANOVA and means (Tukey) using free software Biostat 5.0. It was possible to conclude that the clones 67-9 and 69-1 showed the pulp yield of 46.8% and 42.5% respectively, further studies are needed for the determination of anthocyanins, especially regarding the extraction and preparation of this compound sample for analysis in the spectrometer. The soluble solids present in the pulp remained in greater quantities in the residue of the finisher; pulps Robusta clones evaluated had a significant content of total polyphenols, and deserves further study for its use as a product of high value; clone 67-9 showed a higher content of total polyphenols compared to 69-1, the residue obtained after pulping procedure, extraction and refining in finisher presented interesting composition for further studies for its use, the clone 69-1 showed higher levels of caffeine, tannins, dietary fiber and trigonelline.

**PP 501**

## **SEEPAGE OF RAW AND TREATED COFFEE PROCESSING EFFLUENT FROM PITS.**

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The primary wet coffee processing by-products include coffee pulp and the effluent. The effluent arises from pulping, pre-grading, washing and final grading operations. Except for the final grading effluent, the rest have been of great concern with respect to pollution of the environment in particular during a year with peak crop. However, pollution occurs if the effluent is discharged into the natural surface water ways in a raw state. That has been attributed to the settlement of suspended solids from the effluent onto the seepage pit walls. Consequently, the sealed walls prevent the effluent from seeping into the ground as expected. As a result, pits overflow easily into the surface water ways proximal to the coffee factory. Incidentally, such water ways are also the sources of domestic and coffee processing water. Hence the undesirable effect of upstream coffee factories to those in the downstream. Such a scenario prevails until the sludge is scooped out during the offseason maintenance to restore the performance of the pit.

Otherwise, there is a proposed strategy towards alleviation of pollution from the coffee processing effluent which entails minimization of processing water use followed by removal of suspended solids from the effluent before disposal into the seepage pits. In view of that a study has been undertaken to identify local resources capable precipitating the suspended solids from the effluent. Besides that the percolation of raw versus treated effluent using scaled down seepage pit models has been evaluated and is subject of this paper. The results indicate that seepage of treated effluent from the pits was 2 to 7 times faster than in pits with the corresponding raw effluent. Bearing in mind that the sun drying of coffee and the disposal of effluent depends on the available limited coffee factory land, an upgrade in the performance of the pits would not only ease pollution control but also imply a reduction in the disposal area requirements for the benefit of the drying process. The pits would also be conveniently sited beyond the stipulated critical distance (150m) between the factory and the processing water source. Finally, depending on the material used to remove the solids from the effluent, the settled sludge can become an invaluable by-product for further utilization options while the solids remover would also gain similarly by being suitably used for this purpose.

## PP 502

COMPARISON OF TPC, FRAP AND ORAC ASSAYS  
FOR ESTIMATING ANTIOXIDANT ACTIVITIES OF  
DIFFERENTIAL ROASTS OF ARABICA COFFEE BEANS

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Samples of Arabica coffee were harvested at Zentveld's Plantation in Newrybar (northern NSW) de-pulped, demucilaged and dried under controlled temperature and relative humidity conditions. The drying air temperatures were: 40 °C, 50 °C, 60 °C and 70 °C with corresponding relative humidity of 20%, 15%, 15% and 10% respectively. The coffee samples were subjected to various degrees of roasting including light roasting, medium roasting and dark roasting. The unroasted (green coffee) was used as a control treatment. The standard definition of roasting degree is characterised by temperature, roasting time, colour and percentage of weight loss. The total phenolic composition (TPC), ferric reducing antioxidant power (FRAP) and oxygen radical antioxidant capacity (ORAC). Two-way ANOVA revealed that there were significant effects of roasting process for TPC, FRAP and ORAC. Overall, it was found that drying and roasting temperatures influence the antioxidant activity.

## PP 503

THE QUALITY OF CONILON COFFEE DRIED ON A CONCRETE  
TERRACE IN A GREENHOUSE WITH EARLY HULLING

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The time spent in drying coffee is quite important for choosing the method to be used and for maintaining its quality. A concrete terrace in a greenhouse has often been used by farmers for drying coffee. However, this method requires a great deal of time for the coffee seeds to achieve the proper moisture level for hulling and storage. Thus, the objective of this study was to quantify time reduction as a result of early hulling of conilon coffee (*Coffea canephora*) dried on a concrete terrace in a greenhouse, as well as its quality.

The experiment was carried out in Vila Valério, in the north of the state of Espírito Santo, Brazil. A completely randomized block experimental design was used with four replications and the mean values were compared by the F test (Anova) and the Tukey test(0.05). The coffee fruit was harvested with more than 80% ripe fruit and immediately placed on concrete terraces in greenhouses for drying. The parcels were hulled when they reached 22%, 19%, 16% and 13% (wb) moisture content. Then, the parcels that had not reached the desired 13% (wb) level of moisture content were carried back to the greenhouse to finish drying. The time spent in drying was quantified and coffee quality was evaluated by sensory and chemical analyses, electrical conductivity (EC), potassium leaching (KL), reductor sugars (RS) and total sugars (TS), total titratable acidity (TTA) and soluble solids (SS).

EC, RS, TS, TTA, SS and sensory analyses have the same results for all treatments applied. In addition, the KL result is lower for the coffee hulled with 22% (wb) of moisture content. In regard to drying time, the coffee hulled with 22% (wb) moisture content had a considerably shorter drying time than that for the coffee left until 13% (wb) before hulling, a total of 6 days less.

Early hulling of conilon coffee does not affect its final quality. It is a practical activity that is significantly favorable to coffee farmers, decreasing drying time and improving use of terrace space without loss of coffee quality.

**PP 504**

### **DRYING KINETICS OF NATURAL COFFEE FOR DIFFERENT TEMPERATURE AND RELATIVE HUMIDITY**

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The drying rate of agricultural products is influenced especially by air temperature. However, with coffee, temperatures above 40 °C cause damage which depreciates its quality. Another factor influencing the drying rate of agricultural products is the relative humidity of the air. The drying time, of thin-layer drying of rice grains, may be significantly reduced by reducing relative humidity, particularly when using drying temperatures below 34 °C (Ondier et al., 2010). The study of drying systems, their design and the viability of commercial application may be made by mathematical simulation. An equation describing the rate of thin-layer drying is necessary for simulating thick-layer drying, given that simulation models that are usually based on the assumption that the thick layer is composed of a series of thin layers (Kashaninejad et al. 2007).

Considering the importance of the theoretical study of the drying processes of agricultural products, this study evaluated the thin-layer drying kinetics of Mundo Novo cultivar coffee berries (*Coffea arabica* L.) adjusting different mathematical models to experimental values as a function of dry bulb and dew point temperatures of the drying air. The ripe fruits of coffee were harvested and selected manually. Then, selected ripe berries were sun dried in a suspended bed, until they reached a moisture content of approximately 0.5 kg.kg<sup>-1</sup> (db) (30 - 35% wb) and then, dried with heated air in a thin layer in mechanical dryers until they reach a moisture content of 0.14 kg.kg<sup>-1</sup> (bs). The effects of three dry bulb temperatures (35; 40 and 45 °C) and three dew point temperatures (2.6; 10.8 and 16.2 °C) of the drying air were evaluated. Three relative humidity levels for each dry bulb temperature were obtained by the combination between the dry bulb temperatures and dew point temperatures. The reduction of dew point temperature, for the same dry bulb temperature, consequently reduced the relative humidity. Seven mathematical models were fitted to experimental data to characterize the process of thin-layer drying of coffee berries. The modified Midili and Successive Residues (with two terms) models were the most adequate for describing the drying process. A rise in temperature and reduction in dew point temperature increased the effective diffusivity coefficient and drying rate and reduced drying time. Under the studied conditions, the effective diffusivity coefficient of water in coffee berries varied between  $1.460 \times 10^{-11}$  and  $3.993 \times 10^{-11} \text{ m}^2.\text{s}^{-1}$ , and the activation energy for liquid diffusion, described by the Arrhenius equation, was 57.09 kJ.mol<sup>-1</sup>.

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## PP 505

AERODYNAMICS PROPERTIES OF COFFEE  
CHERRIES FROM *Coffea Canephora*

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Designing the equipment for processing, sorting, sizing and other post-harvesting equipment of agricultural products requires information about their physical properties. Among the properties, terminal velocity is very important. Terminal velocity was measured with a designed vertical wind column using the suspension velocity method. In this study, several physical properties of *Coffea Canephora* clone 83 cv. EMCAPA 8141-Robustão Capixaba in two ripeness stages; green ripe and hard ripe cherries were evaluated as a function of moisture content in the range of 11.90–62.10% (w.b.) and 12.65–66.41% (w.b.) respectively. In green ripe cherries, the average experimental bulk density, true density and porosity were found to be in the range of 500.06 to 642.75 kg/m<sup>3</sup>, from 828.50 to 1097.52 kg/m<sup>3</sup> and from 35.91 to 43.58% respectively. The terminal velocity increased from 8.47 to 11.27 m/s as the moisture content increased. In hard ripe cherries, the average experimental bulk density, true density and porosity were found to be in the range of 488.42 to 636.66 kg/m<sup>3</sup>, from 806.91 to 1101.36 kg/m<sup>3</sup> and from 38.09 to 43.68% respectively. The terminal velocity increased from 9.68 to 12.85 m/s as the moisture content increased. The corresponding value of drag coefficient varied from 0.42 to 0.70 and 0.45 to 0.91 respectively.

## PP 506

MATHEMATICAL MODELING OF DRYING NATURAL COFFEE FOR  
DIFFERENT TEMPERATURES AND LOW RELATIVE HUMIDITY

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Freshly harvested coffee is a product that has certain peculiarities, such as high moisture content, approximately 60% (wb), as well as uneven ripening, which makes it different from other grains grown in large scale (Resende et al. 2009). The drying process is an essential step to avoid fermentation and attack of microorganisms that may compromise the coffee quality. In the development and improvement of the machinery used during the drying of the grains it is very important to simulate and obtain information about the theoretical behavior of the product during drying. This simulation follows the principle of drying successive thin layers of the product, using a mathematical model that satisfactorily represents the loss of water during drying. (Berbert et al. 1995; Giner & Mascheroni 2002).

Faced with the importance of the coffee drying process and its influence on the final quality of the product, the current study aimed at evaluating the kinetics of drying in different air temperatures as in a low temperature at dew point on dry processed fruits of Arabic coffee (*Coffea arabica* L.). The fruits were harvested manually, selecting only ripe fruit, and then subjected to hydraulic separation. The freshly harvested fruits had a water content of  $1.9 \pm 0.1 \text{ kg.kg}^{-1}$  (db) and were submitted to drying under mechanical dryers at three dry bulb temperature (35, 40 and 45°C) for the same dew point air drying temperature (2.6 °C), we obtained, respectively, three levels of humidity (13.1, 10.0 and 7.7 %). Seven mathematical models were adjusted to the experimental data to characterize the drying process of coffee fruits. The choice of model was based on statistical parameters: standard deviation of estimate (SE), mean relative error (P), coefficient of determination

(R2) and the tendency of distribution of residuals. It is concluded that, the Henderson and Pabis modified and Successive Residue models with two terms were the most adequate to describe the drying process, with the Henderson and Pabis modified model chosen for its simplicity. The elevation of the temperature of the dried bulb under the low dew point temperature causes; an increase of the effective diffusivity coefficient, the drying rate and also reduces the time of drying. For the conditions studied, the effective diffusivity coefficient of water to fruits varied between  $1,908$  and  $3,721 \times 10^{-11} \text{ m}^2.\text{s}^{-1}$ . The activating energy for the liquid diffusion, described by the equation of Arrhenius, was of  $52,89 \text{ kJ.mol}^{-1}$ .

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PP 507

## DRYING OF COFFEE BEANS USING AZEOTROPIC ETHANOL

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A coffee dryer using azeotropic ethanol as fuel for heating air, was designed and evaluated. The dryer has a static capacity of 125 kg of dried coffee and consists of three chambers vertically arranged, with a maximum thickness of 25 cm each. A centrifugal fan was designed to supply an air flow of  $12.5 \text{ m}^3.\text{min}^{-1}$  at a static pressure of 7 cm of water column, with a pneumatic efficiency of 62%. The specific flow rate was  $100 \text{ m}^3.\text{min}^{-1}.\text{t}^{-1}$  of dry parchment coffee (dpc), which meets the recommendations of Cenicafé, was obtained using an electronic device that acts on the fan speed to obtain the desired value. To measure moisture during the drying process in real time, and to determine the end of the process, which is when the product moisture is in a range between 10 and 12% wet basis, it was designed an electro – mechanical device, based on dry matter conservation during the process. To heat up air from an environmental average temperature of  $20^\circ\text{C}$  to  $50^\circ\text{C}$  it was designed a shell tube heat exchanger, with a thermal efficiency of 64%.

Five tests were performed using ethanol as a fuel; two with heat exchanger and three mixing directly the air and combustion gasses. In addition 2 tests were conducted using propane as fuel and the air and hot gasses mixture for drying, as a control. The three chambers were simultaneously charged with grain layers from 15.3 to 25.0 cm of height. The average temperature of the drying air was  $50^\circ\text{C}$ . The drying time varied from 14 h to a maximum of 23 h. The average specific consumption of ethanol azeotropic using heat exchanger was  $0.24 \text{ L.kg}^{-1}$  of dpc and  $0.17 \text{ L.kg}^{-1}$  of dpc with direct heat exchanging. When using propane gas, the average specific consumption was  $0.09 \text{ m}^3.\text{kg}^{-1}$  of dpc. The specific emissions using azeotropic ethanol ranged from 28 to  $50.4 \text{ kg of CO}_2.\text{t}^{-1}$  of dpc, with direct and indirect heat exchanging, respectively. Emissions using propane reached values of  $1.600 \text{ kg of coffee CO}_2.\text{t}^{-1}$  of dpc. The specific cost for drying coffee using azeotropic ethanol ranged from U.S. \$  $0.20 \text{ kg}^{-1}$  dpc to U.S. \$  $0.28 \text{ kg}^{-1}$  of dpc, with direct and indirect heat exchanging, respectively. With propane the average specific cost was US \$  $0.09 \text{ kg}^{-1}$  of dpc.

According to the results of this research, azeotropic ethanol produced from a renewable source, is a promising fuel for coffee drying, with favorable environmental impact relative to other fuels in use today. With the development of new technologies for the production of ethanol coming from coffee biomass, in the future production costs could be reduced encouraging its use in Colombia for coffee drying and for other crops.

**PP 508**

**OPPOSED DRUM ROASTER**

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Micro-roasters use small, rotating drum, batch roasting machines to provide freshly roasted coffee to local customers. This is part of the local foods movement underway in many countries.

Uniform mixing of the bean pile is required during coffee roasting so that all beans receive equal heat exposure. However, simple geometry dictates that there would be less uniform mixing and more variation in heat exposure in small drum roasters than in large drum roasters.

Small drum roasters have a much greater surface-area-to-volume ratio than large drum roasters – this means that there are more opportunities for heat transfer between the bean pile and the drum walls as well as the front wall of the roaster. This can lead to variations in heat exposure within the bean pile.

Small drum roasters have a lower tangential velocity than large drum roasters, even when operated at a higher rpm in order to achieve the same rotational Froude number. Since the kinetic energy of beans beginning their cascade down the bean pile varies with the square of tangential velocity, this can result in less uniform mixing in small drum roasters.

Studies conducted on granular media have shown that the effective thermal conductivity of granular media increases with increased mixing and increased shear rate.

The objective of this study was to design and evaluate a small drum roaster with improved mixing ability. The roaster is an opposed drum roaster, with two counter-rotating horizontal drums facing each other. Coffee beans are propelled from one drum to the other by tapered vanes attached to the inside of the drums. Intensive mixing takes place in the center of the roaster and there is less interaction with the front wall of the roaster than in a conventional roaster. Emptying the roaster is achieved by reversing the rotation of the front drum.

Acrylic models of counter-rotating horizontal drums with various vane designs were constructed. The time required for uniform mixing was determined by evaluating videos of mixing trials with white and black beans. After the vane design was selected, an opposed drum roaster of 2.2 kg capacity at 20% degree of fill was constructed and used to roast coffee for sale at local farmers' markets.

This presentation would report on the results of the video trials as well as the results of trials with the actual roaster.

This study would add to the process technology available for the design of small scale batch roasting machines.

PP 509

## EVALUATION OF GAB MODEL TO DESCRIBE THE DESORPTION ISOTHERMS OF COFFEE IN DIFFERENT PROCESSING LEVELS

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Sorption isotherms, which describe the equilibrium relationship between moisture content and relative humidity of the environment, are unique for each product and are used to a better understanding of moisture variations during storage. In view of the importance of understanding the hygroscopicity of agricultural products, this work aimed to determine and model the sorption isotherms of green coffee, pulped coffee and coffee fruit for various temperature and relative humidity conditions using GAB model. Furthermore, the model parameters were obtained and correlated with the drying process of coffee. Coffee fruits (*Coffea arabica* L.), variety "Catuai Vermelho" were manually harvested during cherry stage. Afterwards, fruits were washed and selected for better characterization of the raw material. In order to obtain different means of processing coffee, part of coffee fruits was hulled (pulped coffee) while the rest was processed (green coffee). During harvest, unripened, deteriorated and injured coffee was eliminated. Due to the high initial moisture content of coffee and in order to reduce the risk of microorganisms development, coffee fruits and pulped coffee were submitted to partial drying on yards. Coffee fruits and pulped coffee were dried until moisture content reached 45 % dry basis, and green coffee was dried until 11 % dry basis. This process was obtained by low temperature drying using an air conditioner unity manufactured by Aminco, model Aminco-Aire 150/300. At the end of drying process, the material had its parchment and silver pellicle which involves coffee pulped removed by hand. Equilibrium moisture content (EMC) of green, pulped and coffee fruit were determined using the static method, which is based on the use of saturated salt solutions to achieve constant water activity of samples. Salt solutions used to obtain constant relative humidity were  $\text{NH}_4\text{Cl}$ ,  $\text{KBr}$ ,  $\text{KNO}_2$ ,  $\text{KNO}_3$ ,  $\text{K}_2\text{SO}_4$ ,  $\text{CaCl}_2$ ,  $\text{Ca}(\text{NO}_3)_2$ ,  $\text{Na}_2\text{Cr}_2\text{O}_7$ ,  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ,  $\text{LiCl}$ ,  $\text{LiCl} \cdot \text{H}_2\text{O}$  and  $\text{NaCl}$ . This group of salts allowed a wide range of relative humidity, from 11 % to 95 % RH. Sorption isotherms of green, pulped and coffee fruit were acquired at 10, 20, 30, 40 and 50 °C. Experimental data of equilibrium moisture content were fitted to the Guggenheim–Anderson–de Boer (GAB) model. GAB model has the advantage that its parameters has physical meanings, and its adjustment in describing experimental data is up to 0.90 of water activity. GAB model fitted adequately to the experimental data of desorption process. Equilibrium moisture content increased with the increment of relative humidity and decreased with temperature increase at a constant relative humidity. Monolayer moisture content values had the tendency to decrease with temperature increase. The C constant did not present a defined behavior to the drying of coffee from different processing levels. The K constant had the tendency to increase with temperature increase. Enthalpy values for each coefficient of GAB model were found.

PP 510

THERMODYNAMIC PROPERTIES ANALYSIS FROM DRYING  
PROCESS OF COFFEE IN DIFFERENT PROCESSING LEVELS

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Agricultural products require several post-harvest processes with the goal to prevent and minimize loss that occurs during its storage and commercialization. The developments of dryers, calculations of energy requirement during drying and water properties at food surface are some of the items that thermodynamic properties provide useful information. In view of the importance of these parameters, this work aimed to calculate the thermodynamic properties during the drying process of green coffee, pulped coffee and coffee fruit for various temperature and relative humidity conditions. Coffee fruits (*Coffea arabica* L.), variety "Catuai Vermelho" were manually harvested during cherry stage. Afterwards, fruits were washed and selected for better characterization of the raw material. In order to obtain different means of processing coffee, part of coffee fruits was hulled (pulped coffee) while the rest was processed (green coffee). During harvest, unripened, deteriorated and injured coffee was eliminated. Due to the high initial moisture content of coffee and in order to reduce the risk of microorganisms development, coffee fruits and pulped coffee were submitted to partial drying on yards. Coffee fruits and pulped coffee were dried until moisture content reached 45 % dry basis, and green coffee was dried until 11 % dry basis. This process was obtained by low temperature drying using an air conditioner unity manufactured by Aminco, model Aminco-Aire 150/300. At the end of drying process, the material had its parchment and silver pellicle which involves coffee pulped removed by hand. Equilibrium moisture content (EMC) of green, pulped and coffee fruit were determined using the static method, which is based on the use of saturated salt solutions to achieve constant water activity of samples. Salt solutions used to obtain constant relative humidity were  $\text{NH}_4\text{Cl}$ ,  $\text{KBr}$ ,  $\text{KNO}_2$ ,  $\text{KNO}_3$ ,  $\text{K}_2\text{SO}_4$ ,  $\text{CaCl}_2$ ,  $\text{Ca}(\text{NO}_3)_2$ ,  $\text{Na}_2\text{Cr}_2\text{O}_7$ ,  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ,  $\text{LiCl}$ ,  $\text{LiCl} \cdot \text{H}_2\text{O}$  and  $\text{NaCl}$ . This group of salts allowed a wide range of relative humidity, from 11 % to 95 % RH. Sorption isotherms of green, pulped and coffee fruit were acquired at 10, 20, 30, 40 and 50 °C. Experimental data of equilibrium moisture content were fitted to the Guggenheim–Anderson–de Boer (GAB) model. The integral isosteric heat of desorption and differential entropy of the drying process of cocoa beans increased with decrease in equilibrium moisture content, and this trend also occurred with Gibbs free energy.

PP 511

THE BEHAVIOR OF THE ANTIOXIDANT ENZYMES ACTIVITIES AND H<sub>2</sub>O<sub>2</sub> CONTENT DURING THE DRYING OF ARABICA COFFEE GRAINS

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The onset of germination process and drought stress during the drying of the coffee have been reported by some studies and these processes can generate reactive oxygen species (ROS), which can be metabolized through antioxidant mechanisms. However, studies related to the behavior of the antioxidant enzymes during the drying of the coffee grains were not found in the literature. Considering the importance of the antioxidant mechanisms of superoxide dismutase (SOD), guaiacol-peroxidase (GPOX) and glutathione reductase (GR) as well as the role of the hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) in the oxidative process, the activities of these enzymes and the concentration of H<sub>2</sub>O<sub>2</sub> into the grains were measured during the drying of the natural coffee (dry process) and pulped natural coffee (semi-dry process). The results showed to natural coffee reduced enzymatic activities, as well as the highest contents of hydrogen peroxide compared to pulped natural coffee.

## Acknowledgements

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**PP 512**

## **QUALITY COFFEE (*Coffea arabica L.*) SUBJECTED TO TWO PROCESSING TYPES**

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Coffee is an agricultural product with a quality-based price. Brazil, as a world leader in the production and export of coffee, as well as a great coffee consumer, has sought to meet market demands by innovating and adopting technologies for high-quality coffee production. The coffee market is always in constant changes flux. The goal of the specialty coffee roasters in the United States, the biggest consumer of coffee, are aiming to increase annual consumption, which presently totals approximately 20-21 million bags, by 30% by 2022. Thus, the trends in the coffee trade are directly reflected in Brazilian production. Numerous factors affect coffee quality, genetic (for example, different cultivars) environmental factors (Avelino et al., 2005), and post-harvest procedures (especially in processing, drying, and storage) (Dias et al., 2012) have been considered to be the most important determinants for the sensory profile of coffee beverages. Observations that compare the beverage quality of different commercial cultivars produced in the Brazil and world and/or correlate beverage quality with the effects of different processing techniques are rare.

This study aimed to differentiate the quality of coffee (*Coffea arabica L.*) among genotypes subjected to dry (natural coffee) and semi washed (pulped natural coffee) processing in southern Minas Gerais State, Lavras, Brazil. Six coffee genotypes were characterized, three belonging to Bourbon groups and three commonly cultivated in Brazil. Sensory and chemical analyses were performed, and the concentrations of the following compounds were determined: trigonelline, chlorogenic acid (5-CQA), total and reducing sugars, total soluble solids, and total titratable acidity.

An effect of genotype was evident and the Bourbons exhibited a greater potential to generate better quality beverages compared to the other cultivars (Mundo Novo, Red Catuai and Icatu Precoce). The chemical components 5-CQA and trigonelline contributed to separating the superior quality coffees from the other coffees. In the present study, the natural coffees also had more body compared to the pulped natural coffees. The form of processing is not allowed to discriminate against commercial genotypes (Mundo Novo IAC 502/9, Red Catuai IAC 144, and Icatu Precoce IAC 3282), which were worst sensory quality. The Yellow Bourbon A.C/Carmo de Minas genotype produced better quality coffee regardless of the processing type. The beverage quality of the Yellow Bourbon Procáfe/Varginha cultivar was better when natural than pulped natural coffee processing.

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PP 513

EFFECT OF FACTORS OF COFFEE FERMENTATION  
ON CUP QUALITY**PUERTA-QUINTERO, Gloria Inés.\***

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In this work the kinetics of degradation of total and reducing sugars of coffee mucilage as well as the formation of alcohol and acidity during fermentation at room temperature and under refrigeration was determined and also it was analyzed the changes in pH and Brix of the mucilage and the quality of brewed coffee, according to the time and fermentation system. The rate of chemical changes in the mucilage during fermentation depended on the external temperature and time. At room temperature the concentration of sugars in the mucilage decreased according to an exponential function, first order kinetics, and therefore, was faster in the first hours of fermentation, and, at 18 hours was degraded 26% of total sugars of fresh coffee mucilage, half of the initial sugar concentration at 40 hours, but at the same times on cooling only 8.6% and 18.3%. Similarly, the fermentation kinetics of the reducing sugars of mucilage of coffee was faster at room temperature than refrigerated. Thus, after 18 hours at 20.5 °C the mucilage presented 3.2% of reducing sugars, at 30 hours 2.6%, and half were fermented at 40 hours, while by cooling at 18 hours only about 10% of reducing sugars fermented and to 40 hours 21%. At 20.5 °C, the acidity and concentration of alcohol of coffee mucilage increased with fermentation time to reach a maximum value, but by cooling lactic and alcoholic fermentations were delayed.

Brix changes over time in coffee fermentation systems without water, both open and closed, fitted to a first order kinetics, and the rate was slower by reducing the external temperature, and faster in closed than open. By contrast, in submerged systems the values of Brix increased as fermentation progressed, but without a defined behavior. On the other hand, the values of pH in coffee fermentation systems both open and closed and submerged and solid substrate decreased to a minimum, not less than 3, in a time that depended on fermentation system and temperature.

The time and fermentation system influenced the quality, flavors and aromas of brewed coffee. To ensure the quality of coffee is to perform the following good practices in the process: - standardize the quality and maturity of the pulped coffee - choose the fermentation system – fixing the fermentation time, 12 to 18 hours for solid substrate and less than 30 hours in submerged substrate, - measure the pH of the substrate during fermentation, - stop the fermentation when the mucilage present pH values between 3.7 and 4.1, wash the coffee beans using clean and quality water until removing degraded mucilage - dry coffee in thin layers immediately after washing.

Keywords: coffee, fermentation, quality, sugars, pH, Brix, acidity, alcohol, kinetic

**PP 514**

## DEVELOPMENT OF AN HYBRID ROASTING PROCESS FOR THE CREATION OF NEW ROASTING- AND FLAVOR-PROFILES WITH SPECIAL ATTENTION TO THE OPTION OF SHORT-, MIDDLE- AND LONG-TERM ROASTING

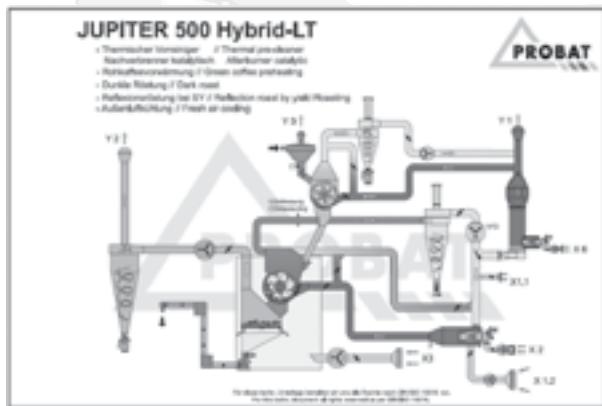
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In many cases the demand is placed to carry out also long-term roasts (12 – 20 minutes) on short-term roasters (roasting times of 1.5 – 4 minutes). Owing to the possible air-bean ratio this does, however, result in differences in flavor in comparison with classic long-term roasters.

The possibility of a flexible setting of roast supply air temperature, roasting air volume and bean distribution in the roasting chamber was analyzed in the course of more than 1,200 trial roasts. Sensory and chemical analysis techniques were applied for the appraisal. Hot air feeding system, mixing elements and water quenching were redeveloped within the scope of transfer to an industrial roasting machine. The entire procedural process management as well was adapted to the target requirements. The cooling process in combination with water quenching was optimized through the application of new thermal analytical options.

Based on the research results a roaster with a capacity of 500 kg/h was built to carry out further trials.



First analyses of trial roasts by means of HPLC, GC-MS and cupping groups show that it is possible to achieve the classic short- and long-term roasting profiles. Owing to the flexible combination of setting parameters also other roasting profiles with new taste profiles can be achieved. This flexibility is of particular advantage since specific chemical components regarded as requested resp. unrequested when discussing about health effects can be specifically influenced.

The already available results are to be confirmed and deepened by further trials and analyses during the next months. Already now it becomes clear that new options for the creation of roasting profiles as well as of the flavor development are resulting from this new "hybrid" roasting process.

PP515

## BIODEGRADABLE POLYURETHANES (PU) DERIVED FROM AGROINDUSTRIAL WASTES: THE CASE OF COFFEE BEANS.

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Agroindustry processes are one of the main economic activities in Costa Rica. To obtain the final product, many others sub-products are generated which might pollute if they do not receive adequate treatment. However, those wastes could be used as raw materials for making more useful compounds from an industrial point of view. Some cases are: banana, coffee bean, sugar cane and pineapple.

PU is one of the most useful three-dimensional polymers, commonly prepared by reacting diisocyanates, as diphenylmethane diisocyanate (MDI), and polyols as polyethylene glycol (PEG).

Several researchers have described the use of renewable materials as polyols for polyurethane (PU) preparation. In this case, we obtained biodegradable composite polyurethanes from agro-based fibers as reinforced material, using pineapple, coffee beans, among others fiber wastes.

From ecological considerations PU's containing this kind of natural polymers is beneficial, since it is possible to convert an agricultural waste into useful biodegradable materials.

In the present study, the use of several agroindustrial wastes in PU foam preparation and their physical-chemistry properties were investigated.

Results indicated that solubility of solid wastes in PEG was dependent on conditions such as particle size of waste powder, heat-treatment temperature and time, molecular weight of PEG (OH groups to react with MDI), PEG/agroindustrial waste ratio. So, polyurethane foams were successfully prepared from agroindustrial waste solutions. It was demonstrated that lignocellulose acts as a hard segment in PU molecules. Finally, the agroindustrial wastes decreases the thermal stability of polyurethanes.

## PP 516

HEAT-INDUCED ACCELERATION OF CO<sub>2</sub> DEGASSING  
FROM ROASTED COFFEE BEANS**BEZMAN, Yair, COHEN, Zion, OFEK, Ayelet, BENSAL, David, KARKAR Samir**

Coffee Technology Center, Strauss-Coffee BV, Lod Israel

The objective of this study was to evaluate the impact of heating roasted coffee beans on carbon dioxide release volume, for the purpose of shortening degassing time of the roast and ground coffee. One kilogram of freshly roasted Robusta or Arabica beans were heated from ambient to 80°C for a period of 4 hours in cylindrical chamber under Nitrogen or Air stream. At the end of the heat treatment, the beans cooled to ambient temp, grinded and immediately packed under inert conditions in soft packages. A sample of the roast and ground coffee was taken directly from the grinder to CO<sub>2</sub> release measurement. Treated packed coffee was periodically assessed by analytical means for freshness, volatiles loss and water content in comparison to a control. Sensory evaluation was correspondingly carried by comparing to the control. Swelling of the packages was additionally compared. The heat treatment of the roasted beans resulted in an average of 33 percent reduction of CO<sub>2</sub> release from the ground coffee and packages' swelling was significantly reduced.

## PP 517

OPTIMISING COFFEE EXTRACTION USING A  
MULTISCALE APPROACH.**MELROSE, John\*, CORROCHANO Borja \*\*, NORTON, Mark\*, SILANES-KENNY, Javier \*, FRYER, Peter \*\*, BAKALIS, Serafim\*\***

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This work will report a recent study of espresso style extraction as a coupling of processes occurring at two different scales: diffusion from grains ( $\sim\mu\text{m}$ ) and convection within a packed bed ( $\sim\text{cm}$ ). In order to build the model we measured the porous microstructure of a single particle and a bed. Porosity and skeletal density were assessed using Hg porosimetry showing the former an average value of 54%. At the bed scale, permeability was measured using a custom pressure rig. Steady state porosity of the bed was also calculated assuming the Kozeny-Carman permeability relation. Using this data, in a mathematical model of coffee extraction, results will be presented to show how both grind size and the level of fines affects coffee yield and drink strength, but also drink volume in a given time, and extraction pressure. We will also re-examine the controversial debate around wash vs diffusion extraction mechanisms. Overall, some fundamentals and some myths surrounding coffee preparation will be explored.

**PP 518**

**STORAGE OF GREEN COFFEE IN HERMETIC PACKAGING**

**RIBEIRO, Fabiana\_Carmanini\*, BORÉM, Flávio MEIRA\*, FIGUEIREDO, Luisa Pereira\*, GIOMO, Gerson Silva\*\*, COLPA, Samuel Ramalio Coste\*, RIBEIRO, Diego Egídio\*.**

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Coffee is an agricultural product with a quality-based price. The value of coffee increases significantly with improvements in quality, which are necessary to obtain new markets. During roasting, the taste and aroma of coffee develop from ingredients originally present in raw beans. Taste and aroma are the principal factors affecting beverage quality. The presence and development of the taste and aroma precursors in raw coffee beans depend on genetic, environmental, and technological factors (Alpizar and Bertrand, 2004; Farah et all, 2006).

Traditionally, green coffee beans have been stored in jute sacks. Jute is most frequently used because it is readily adaptable to smallscale commerce and because it is easily sampled for lot inspections. Elevated operational costs that result from the need for manual handling represent one disadvantage of storage in jute sacks. Another disadvantage is rapid deterioration in quality when the beans are stored in warehouses without ambient air control. Containers called "big bags" represent another form of storage used in Brazilian warehouses. The ease of mechanized handling, along with operational economies of scale, represent the principal advantages offered by this method of storage. However, big bags, like jute sacks, have the disadvantage of being permeable to water vapor and to gases present in ambient air (Borém et all, 2008).

The aim of the present study was to evaluate changes in the color and beverage quality green coffee beans (*Coffea arabica L.*) after 12 months of storage in an artificial atmosphere. The evaluation consisted of a 2 x 2 factorial design with three replicates, two storage conditions (hermetic big-bags with and without CO<sub>2</sub> injection, i.e., a modified atmosphere and a controlled atmosphere, respectively) and two sampling positions (upper and lower). Two additional treatments were studied as controls: jute sacks and GrainPro sacks. The beans were qualitatively evaluated for their color and for their beverage quality attributes including their sweetness, acidity, flavor, body and aftertaste. The evaluation was performed by a group of 13 judges certified by the Specialty Coffee Association of America (SCAA). The beans packaged in impermeable containers were more frequently given classifications of green color and current crop. The frequencies for the attributes of sweetness and acidity were consistently lower when the beans were packaged in jute sacks. The beans packaged in hermetic big-bags with an injection of CO<sub>2</sub> maintained a specialty coffee classification after 12 months of storage.

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PP 519

## CUP QUALITY INFLUENCE OF 5 PRIMARY PROCESSING METHODS ON INDONESIAN ARABICA COFFEE

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This research investigated the cup quality influence of 5 primary processing methods on Arabica coffee by using experienced specialty industry cuppers to preference rank these coffees in blind cupping sessions. The 5 coffee processing methods evaluated were *Pulp Natural (PN)*, *Full Washed (FW)*, *Wet Hulled (WH)*, *Pulp Natural and Wet Hulled (PN/WH)* and *Demucilager (DM)*.

Fresh coffee cherry of a single Arabica variety, *Andung Sari 2K (AS 2K)* from a 2 ha plot in the ICCRI research station was harvested and processed to dry coffee by 5 different processing methods with three replications. The cup consistency of the 3 replications within each process were confirmed then combined to produce 5 composite samples representing each process. 13 coffee cuppings in 4 separate cupping sessions in Indonesia and Australia by trained cuppers from the specialty coffee industry evaluated the 5 samples by using preference ranking methodology, ranking the 5 coffees from “Most Preferred” to “Least Preferred” in blind cupping sessions.

The results from the cupping sessions indicate that processing method has a clear effect in the cup quality and flavor profile. The processing method described by the various names of “Pulp Natural” / “Descascado” / “Honey Coffee” was the clear preference of specialty coffee industry cuppers in blind cupping sessions when coffee had matured, (between 6 to 9 months), where, 100% of cuppers ranked it as «Most Preferred». When the *PN* was fresh, (less than 3 months), no cuppers ranked *PN* as «Most Preferred».

Proper storage of specialty coffee is understood to be an integral part of the quality assurance process to maintain cup quality. This research has demonstrated that the sweet, floral and complex cup profile created by *PN* processing is highly desirable and that the storage phase of this process is an essential step in developing this cup quality.

**Keywords:** *Coffea arabica*, specialty coffee, pulp natural, cup taste.



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## POSTER SESSIONS

**Wednesday, November 14, 2012**

**Biotechnology & Agronomy**



PB 200

## INFLUENCE OF THE ENVIRONMENT IN THE PRODUCTION OF SOMATIC EMBRYOS OF COFFEA ARABICA CV. CATURRA ROJO IN EMBRYOGENIC CELL SUSPENSION CULTURES AND BIOREACTORS.

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Research to establish regeneration systems via somatic embryogenesis and increased their efficiency has traditionally focused on the study of the components of culture medium. A factor which received only little attention in the process of somatic embryogenesis is the influence of the *in vitro* environment in the culture vessel. This research was conducted in order to determine the effect of carbon dioxide on somatic embryogenesis of Coffea arabica L. cv. Caturra rojo and the production of somatic embryos in bioreactors. In embryogenic cell suspensions was observed a higher somatic embryo formation at concentrations of 2.5 and 5.0% compared with 10.0% CO<sub>2</sub> and controls, plus a greater number of torpedo-stage embryos. The process of induction and differentiation of somatic embryos and CO<sub>2</sub> concentrations were related to the behavior of pH in the culture medium. In the bioreactor, the culture vessel configuration and specifically the aeration system, influenced on the accumulation of CO<sub>2</sub>. In the control bioreactor without forced ventilation where CO<sub>2</sub> levels accumulated up to 2.8% was achieved increased production of somatic embryos in bioreactors with forced ventilation. By increasing the concentration of CO<sub>2</sub> to 2.5% had more synthesis of AGPs which coincided with the highest values of somatic embryo production. The inhibitory effect linked to the embryogenic process in the presence of Yariv reagent showed the role of AGPs in the morphogenesis via somatic embryogenesis, opening the possibility of using these molecules as molecular markers of somatic embryogenesis. The process of differentiation of globular stage embryos was stimulated with a concentration of 5.0% CO<sub>2</sub>, yielding the highest proportion of torpedo-stage embryos with low levels of birth defects. The germination of torpedo-stage embryos were favored with concentrations of 2.5% yielding low percentages of malformed embryos.

PB 201

**BIOLOGICAL AND MOLECULAR CHARACTERIZATION  
OF ISOLATES OF THE ENTOMOPATHOGENIC FUNGUS  
*BEAUVERIA BASSIANA* (BALSAMO) VUILLEMIN****ECHEVERRÍA-BEIRUTE, Fabián**

Center for Coffee Research (CICAFE), Costa Rican Coffee Institute (ICAFE)

The coffee berry borer (*Hypothenemus hampei*) is one of the most important pests in the Costa Rican coffee plantations. The biological control strategy is preferred, by using the entomopathogenic fungus *Beauveria bassiana*. In order to determine the attributes for insect control within fungi isolates, 10 different monosporic isolates collected from different parts of the country, were evaluated under controlled laboratory conditions, including the variables of Daily Radial Growth Rate (DRGR), spore production, ultraviolet light resistance and pathogenicity against the coffee berry borer. The study was conducted in 2005 in the Phytopathology Laboratory of the Center for Coffee Research (CICAFE) in San Pedro de Barva, Heredia, Costa Rica. Additionally, the isolates were molecularly characterized in the Molecular Biology Laboratory of the Technological Institute of Costa Rica (ITCR), in Cartago, using eight specific microsatellite primers. For DRGR, results demonstrated that there are no significant differences ( $P=0.05$ ); however, for spore production, it was found that statistically ( $P=0.01$ ) they are separated into two types: high and low sporulation. The germination of spores irradiated for 30 minutes was above 82 percent in six isolates, and three of them reached 100 percent, demonstrating the possibility of mechanisms to prevent the damage caused by that mutation source. The assessment of the coffee berry borer aggressiveness revealed 100 percent colonization before day 12 of initial exposure in three strains. By the other hand, molecular characterization revealed that seven of the eight pairs showed high allelic variability, facilitating the creation of a dendrogram. The groups of isolates showed great diversity, and all of them were considered as strains. They were not much phylogenetically related, especially in the case of two of them, which were widely separated. No biological or geographic association could be correlated with any classified group.

## PB 202

## ACCLIMATIZATION OF F1 HYBRIDS REPRODUCED IN VITRO

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The multiplication of F1 hybrid materials consists in the cloning of the mother plant by means of tissue culture. This process is performed in the laboratory until a level of development reach and then requires to transfer from a highly controlled environment in the laboratory to an external, fluctuating environment. For this reason, as a preliminary to development in the nursery, *in vitro* propagated plants must go through the acclimatization phase in a greenhouse. In order to evaluate different methodologies for adaptation of seedlings from a controlled *in vitro* environment to an *ex vitro* environment, different substrate mixtures were evaluated for planting seedlings in trays under the same humid chamber system, humidity and temperature conditions. The experiment was conducted in the greenhouse of the agricultural center of Centro Agrícola Cantonal, Grecia, Alajuela, Costa Rica, with *in vitro* material of the Centroamericano variety, provided by the Biotechnology Laboratory of the Tropical Agricultural Research and Higher Education Center (CATIE), Turrialba, Cartago. The substrates used were Soil-Shrub, Rice Chaff (TBG, in Spanish), Soil-Organic Manure-Rice Chaff (TAG, in Spanish), Soil and Coconut Husk Fiber (TF in Spanish) and Compressed Peat (Jiffy). The development of seedlings was evaluated for four weeks, calculating mortality and etiolated plants according to treatment. With the methodology used, there were 90 percent of acclimatized plants in three weeks. The highest mortality rate was observed in the coconut husk fiber substrate. The results showed a lower percentage of dead seedlings in Jiffy, but a higher percentage of etiolated plants. In the study, it was found that the use of substrates such as Soil-Shrub-Rice Chaff and Jiffy contributes to an adequate seedling development, as long as the entry of light is reduced in the early days, and substrate is moisture saturated.

## PB 203

PHENOLOGY OF COFFEE FRUITS IN RELATION TO COFFEE BERRY BORER (*Hypothenemus hampei*) ATTACKS**ROJAS, Mainor; GAMBOA, Adrián; MORA, Mauricio; ALFARO, Ronny; RAMÍREZ, Guillermo; ARAYA, Juan; MURILLO, Pablo; RODRÍGUEZ, Leopoldo; ARIAS, José; FALLAS, Carlos; RODRÍGUEZ, Oscar**

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The attacks of the coffee berry borer (*Hypothenemus hampei*) start 40-50 days after blooming, but generally, the insect reproduces until the coffee fruit has accumulated 20 percent of dry matter. The purpose of these studies was to calculate the number of days between blooming and the moment in which the coffee fruit reach 20 percent of the dry matter in 19 Costa Rican coffee areas.

Research was conducted during 2002, 2003, 2004 and 2006 in Pérez Zeledón (four locations), Buenos Aires de Puntarenas, Coto Brus, Cartago, Acosta, Tarrazú, Valverde Vega, Turrialba, Paraíso, Atenas, San Ramón, Poás, Tres Ríos, Puriscal, Grecia and León Cortés, in ranges from 550 to 1740 m.a.s.l. The fruit development was studied in multiple and one-time blooming. The fruit samples were collected from shoots previously marked in the plants selected every two weeks and were taken to the laboratory to determine their dry weight.

The number of days between blooming and the moment when the fruits reach 20 percent of dry matter differed depending on the location and the prevailing weather conditions in each area. In general, it was found that the fruits accumulate dry matter faster in the lower areas, while more time is required in the higher areas for the coffee berry borer to reproduce inside the fruits. The results indicated that because of the Costa Rican coffee growing conditions the coffee berry borer can start laying eggs 100 days after bloom in the lower areas and up to 172 days after bloom (DAB) in the higher areas. The pest management practices, such as applying *Beauveria bassiana* should be performed at least one month before the fruits accumulate 20 percent of dry matter.

**PB 204****ASSESSMENT ON RELEASING THE *Prorops nasuta* TO CONTROL THE COFFEE BERRY BORER IN TURRIALBA****ROJAS, Mainor; OBANDO, Juan; DELGADO, Carlos; GUERRERO, Giovanni.**

Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)

The purpose of the study was to evaluate the establishment of *Prorops nasuta* and its control on the coffee berry borer in the coffee growing area of Turrialba, Costa Rica. The parasitoids were released in 20 farms (31.3 ha) between December 2007 and February 2008. At the beginning, the coffee berry borer total in different stages was between 9.8 and 14.2 individuals per fruit. The release relation was between 0.08 and 9.9 parasitoids per fruit infected with the coffee berry borer. Samples of fruits infected were dissected during the 2008 postharvest. The establishment and spread of the parasitoid were studied during the 2008/2009 harvest and the 2010 postharvest.

The average levels of parasitism after release reached 17, 28, 28 and 27 percent for the first, second, third and fourth months, respectively; with 6.0, 4.3, 4.1 and 4.3 stages of the parasitoid per parasitized fruit, respectively. A month after the release *P. nasuta* reduced the coffee berry borer population of eggs and adult insects in more than 80 percent and the first-instar larvae in 70 percent, in relation to the fruits with no parasites. At the beginning of the 08/09 harvest, there were parasitoids in 78 percent of the plots, and there were found parasitoids at 50 and 200 meters of the release plot in 44 and 33 percent of the farms, but the values decreased during the harvest.

In the 2010 postharvest, there were parasitoids in 62 percent of the release farms and in 71 percent of the sampled farms with no release, even at several kilometers from the release site. *P. nasuta* was found in 90 percent of the cases in the fruits in the plants and 40 percent in the fruits on the ground. It was concluded that the parasitoid was established and spread in the coffee plantations, providing good control of the coffee berry borer and showing its potential within the integrated pest management.

**PB 205**

**MICROSATELLITE MARKERS IN ANALYSIS OF RESISTANCE  
TO COFFEE LEAF MINER IN ARABICA COFFEE**

**PADILHA, Lilian\*, PEREIRA, Gabriella S\*\*, VON PINHO, Edila V.R., TEIXEIRA\*\*, Rita K. S., CARVALHO\*, Carlos H.S., MALUF\*, Mirian P., CARVALHO\*\*, Bruna L.**

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The objective of this study was to analyze coffee (*Coffea arabica*) genotypes resistant to the coffee leaf miner (*Leucoptera coffeella*) using microsatellite markers. Sixty-six loci were evaluated, of which 63 were obtained from the Brazilian Coffee Expressed Tag (EST) database. These loci were amplified in bulks of individuals from  $F_5$  progenies of 'Siriema' (*C. arabica* x *C. racemosa*) resistant and susceptible to the insect, in eight samples of *Coffea racemosa*, and in an  $F_6$  population of 'Siriema' segregating for resistance to leaf-miner with 91 individuals. Polymorphisms were verified for two SSR loci in bulks of the susceptible progenies. The two polymorphic alleles were present in around 70% of the susceptible genotypes in  $F_5$  and in approximately 90% of the susceptible individuals in  $F_6$ . However, the polymorphic EST-SSR markers among populations contrasting for resistance to leaf miner attack were not correlated to the characteristics studied.

**PB 206**

**TBIO- A MODEL OF STARTUP WITH FOCUS IN  
BIOTECHNOLOGICAL SOLUTIONS FOR COFFEE CHAIN.**

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Tbio is a startup created to give support to commercialize the products of a biofactory installed in the Federal University of Lavras, Minas Gerais State, Brazil, as part of the Innovation Program developed by this University. Its specialty is to innovate, through biological solutions with a vision of the future, since there is in course a strong demand, of the food and beverages consumers, by final products free of chemical residues and with lower employing of them along the production chain. The innovative products are generated from tested microorganisms relative to its capacity to promote yield protection, pests and disease control, desmucilage acceleration and waste water treatment, improvement of process that depends of faster solubilization, like natural phosphate fertilizers. The products are in different phases of development since a biological agent of coffee quality protection, is already in register step with a patent required, a agent of desmucilage acceleration is in the phase of complete laboratorial test, a phosphate solubilizer with the process studied and also with a patent required, a bioinsecticide with a developing project sent for a financial support institution (FAPEMIG). All products have a technological base since they are developed through results obtained during a long time of research developed by the startup partners like Federal University of Lavras-UFLA, Agricultural and Livestock Minas Gerais State Research Institution-EPAMIG. This is the first biotechnological startup born into the Innovative Government Program with the focus in coffee quality and yield improvement into a sustainability concept.

Acknowledgements: To Technological Innovation Center-NINTEC/UFLA, and to Support Research Foundation of Minas Gerais State- FAPEMIG.

**PB 207**

**PRODUCTIVE PERFORMANCE OF TIMOR HYBRID ACCESS TO THE GERMPLASM BANK OF MINAS GERAIS<sup>1</sup>**

**GUEDES, Janine M.<sup>2</sup>; REZENDE, Juliana C.<sup>3</sup>; CARVALHO, Alex M.<sup>2</sup>; MENDES, Antonio N.G.<sup>2</sup>; REZENDE, Ramiro M.<sup>2</sup>, BOTELHO, Cesar E.<sup>3</sup>; CARVALHO, Gladyston R.<sup>3</sup>; MORAIS, Paulo R.F.<sup>2</sup>**

<sup>1</sup> Financial Support: Instituto Nacional de Ciência e Tecnologia do Café – INCT/Café; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Secretaria de Estado de Ciência, Tecnologia e Ensino Superior; Consórcio Pesquisa Café

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The leaf rust (*Hemileia vastatrix* Berk. & Br) is the major disease of coffee (*Coffea arabica*) in Brazil, with production plants are not significantly affected when running suitable phytosanitary treatments. There is great demand from Brazilian coffee growers, new cultivars that contribute to an effective reduction of crop losses caused by leaf rust and to increase the productivity. This work aimed to evaluate the performance in 152 access of the Timor Hybrid in the Germplasm Bank of Minas Gerais, located at the Experimental Farm in Epamig Patrocínio-MG. It was analyzed the productivity and vegetative vigor. The result showed that there was genetic variability among accessions of the bank, and fifty-five accessions were more productive than others, indicating a possible success of selecting superior accessions for use in breeding programs.

Key-words: coffee, yield, vegetative vigor.

**PB 208**

**CRYOPRESERVATION OF *Coffea arabica* L. cv. CATUAÍ VERMELHO EMBRYOS**

**PINTO, Maísa de S.\*, PAIVA, Renato\*, VARGAS, Daiane P.\*\*, SILVA, Diogo P. C. da, SILVA\*, Luciano C. da\*, PAIVA, Patrícia D. de O.\*, NERY, Fernanda C.\*\*\***

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The conservation of vegetal genetic resource is important to prevent the process of genetic erosion of economic and ecological important species. The most ordinary form of genetic conservation is the seed banks; however the seeds of some species, like *Coffea arabica* L., do not tolerate conservation for a long period. Cryopreservation is an alternative form to conserve genetic resources a long period. The objective of this study was to cryopreserve embryos of *Coffea arabica* L. cv. Catuaí Vermelho IAC 144. Different dehydration times in silica gel were tested with moisture content set for each treatment. After 24 hours in liquid nitrogen and 7 days in MS medium, the percentage of germinated embryos was determined. The tetrazolium test was used to evaluate embryo viability after freezing. After 120 days in MS medium, the seedlings were acclimatized. Embryos that were not dehydrated did not survive after freezing, however after the decrease of moisture content an increase in survival rate was observed, with maximum rate (98%) reached following dehydration for 117 minutes. Highest viability (60%), based on the tetrazolium test, was reached when embryos were dehydrated for 108 minutes. Seedling acclimatization was successfully obtained showing 100% survival. Although the cryopreservation of zygotic embryos was successful, no somatic embryos were able to be cryopreserved. None of the dehydrated embryos or dehydrated and frozen somatic embryos survived.

Financial support: FAPEMIG, CNPq, INCT/Café and CAPES.

## PB 209

DIRECT SOMATIC EMBRYOGENESIS AND PLANT  
REGENERATION FROM COTYLEDONARY LEAVES OF  
*Coffea arabica* L. cv. CATUAÍ VERMELHO**PINTO, Maísa de S.\*, PAIVA, Renato\*, SILVA, Diogo P. C. da\*, PAIVA, Patrícia D. de O.\***

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*Coffea arabica* L., a species that presents an economic importance in Brazil, is propagated mainly by seeds. However, this kind of propagation increases the genetic variability between seedlings reducing the uniformity in the field. Tissue culture is an alternative to propagate the species maintaining the uniformity and increasing the multiplication rate of the seedlings and somatic embryogenesis is one of the tissue culture techniques that allow the production of clones from explants obtained from the mother plant. The objective of this study was to develop a protocol for direct somatic embryogenesis using cotyledonary leaves of *Coffea arabica* L. cv. Catuaí Vermelho IAC 144. During the *in vitro* induction of somatic embryogenesis, the effects of different concentrations of BAP in combination with ABA during the maturation phase were observed. Different carbon sources were used for embryo germination and after germination the embryos were rooted using different concentrations of NAA. The influence of three substrates in the survival rate during acclimatization was also observed. Presence of somatic embryos was observed in all BAP concentrations tested with the maximum number (1.10) obtained using 18.35 mg L<sup>-1</sup> BAP. No significant difference was observed in the number of mature somatic embryos in the presence of ABA. All used carbon sources, except sorbitol, were efficient to promote germination of somatic embryos, reaching an average germination of 74%. The presence of roots was observed in all NAA concentrations. After rooting, the seedlings were successfully acclimatized in all tested substrates reaching a survival rate of 94%.

Financial support: FAPEMIG, CNPq, INCT/Café and CAPES.

## PB 210

ESTIMATE OF GENETIC PROGRESS IN PROGENIES OF  
COFFEE ARABICA BY DIFFERENT SELECTION CRITERIA\***REZENDE, Juliana Costa de\*\*, BOTELHO, Cesar Elias\*\*, OLIVEIRA Antonio Carlos Baião de\*\*, SILVA,  
Felipe Lopes da\*\*, CARVALHO, Gladyston Rodrigues\*\*, PEREIRA, Antonio Alves\*\***

\* Financial support: Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Instituto Nacional de Ciência e Tecnologia do Café – INCT CAFÉ; Consórcio Pesquisa Café.

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In order to investigate the aspects related to the use of selection indexes in arabic coffee breeding, analytical procedures were used: index based on the sum of ranks of Mulamba & Mock (ISP), index of desired gains of Pesek & Baker (IGD), classic index of Smith & Hazel (IC), base index of Williams (IB), and direct and indirect selection (SDI). Thirty-nine progenies were evaluated in the 4th generation by selfing after the 2nd backcross between "Catuai" and "Mundo Novo". The evaluations were realized in coffee plants from 30 months old on, having the following characteristics: yield of eight harvests, classification for blend 16 and over, percentage of floating fruits, vegetative vigour and percentage of flat beans. The analytical procedures of selection indexes showed possibilities of applications in advanced generations of breeding being superior when compared with (SDI). The (IGD) was not appropriate in the situation analyzed in this work. The selection based on (IC) and (IB) was the criteria that showed the best results in terms of gains in yield and grain size, and in the distribution of gains in the other characteristics.

Keywords:: *Coffea arabica*. Genetic breeding. Estimates of parameters.

**PB 211**

## **GENETICS CHARACTERISTICS OF POPULATIONS OF ROBUSTA COFFEE IN THE SÃO PAULO STATE, BRAZIL.**

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The high demand by the robusta coffee (*Coffea canephora* Pierre ex A. Froehner) in the last years requires that the Coffee Genetic Improvement Program be intensified in order to provide a new cultivar in the future. The knowledge of the germoplasm, mainly the available genetic variability, is fundamental condition. In this sense, the quantitative genetic offers a series of information, without additional cost, that will help the breeder carry out the selection of better genotypes in efficient form. The objective of this research was to estimate genetic parameters of two populations of robusta coffee in São Paulo State, Brazil. It was installed two experiments of robusta coffee in Institute Agronomic of Campinas - IAC, (Brazil), in the randomized complete block design. The first experiment, named EP 529, was composed by 28 treatments (clones), with three replications and four plants per plot. The second experiment, named EP 530, was composed by 30 treatments (half-sib progenies), with four replications and eight plants per plot. In the two experiments four harvests were carried out. The variance analyses estimated the genetic variance, environmental variance, phenotypic variance, individual and means heritability coefficients, the genetic and environmental variation coefficients and the b index, representing the ratio between the coefficient of genetic variation and the coefficient of experimental variation, not influenced by the mean of the character. In the experiment EP 529 the most favorable year for the selection was the fourth harvest, with high yields and high genetic variability, important conditions for an improvement coffee program. In this harvest, the genetic parameters were larger than, in other harvests and than average of the harvests; the heritability of the mean and at individual level were, respectively, 0.93 and 0.54; the genetic and environmental variation coefficients were 48.30% and 5.43%, respectively, and the b index was 8.90 (a value that is equal or larger than 1.0, in trials with maize indicate conditions that are highly favorable to the selection). The heritabilities of the means showed high estimatives, more than 0.72 and the individuals were over 0.28. In all the harvests the b index was over 1.0. The environmental variation coefficients mean dropped 9.07%, varying between 58.86% and 5.43%. In the experiment EP 530 the fourth harvest too presented the largest productivity, the v index and the higher mean and genetic variability. The environmental variation coefficients were 27.59% and 67.95%; the heritabilities means were 0.17 and 0.54 and individuals were 0.05 and 0.32; the genetic variations coefficients were 7.33% and 30.64% and the b index was 0.46 and 1.17. These experiments indicated the existence of genetic variability inside the treatments and that the selection inside will be able to be performed. In both experiments the mean production of the four harvests was not the more favorable to the selection, being the fourth one more indicated for such procedure. All of the genetic parameters estimated in the experiment of progenies were lower than in the clonal experiment, showing that the fixation of the genotype through assexual reproduction is quicker than sexual reproduction.

## PB 212

## COFFEE BIOTECHNOLOGY: IT'S POTENTIAL IN IMPROVEMENT OF COFFEE PRODUCTION IN KENYA.

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There is tremendous scope for the application of biotechnology approaches in coffee genetic improvement in Kenya. Existing systems involve *in vitro* regeneration and mass propagation of superior *c. arabica* hybrid genotypes via somatic embryogenesis as well as nodal culture. Also, development of *in vitro* regeneration protocols for selected commercial *c. arabica* varieties of importance to breeding programs are at an advanced stage. The synchronization of somatic embryos using various plant growth regulators in addition to identification and differentiation of pre-embryogenic callus, have advanced *in vitro* regeneration techniques of coffee in Kenya. However, the utilization of *in vitro* regeneration techniques along with other biotechnology approaches such as genetic transformation, for improvement of coffee production and other research objectives is yet to occur. The current status and potential of biotechnology approaches in supplementing efforts of breeders in coffee genetic improvement shall be discussed.

## PB 213

CARACTERIZATION OF COFFEE GENOTYPES (*Coffea arabica* and *C. canephora*) FOR ALUMINIUM TOLERANCE IN SOIL**EL AYOUBI, Bilal\*, BUSTAMANTE, José\*, TORRES, Ángel\*\*\***

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Aluminum is one of the most abundant elements in the world. Soils with low pH can delay and prevent the normal plant growth or even cause the plant death due to a lesser absorption of nutriments. The objective of this work was to evaluate the coffee genotypes (*Coffea arabica* and *C. canephora*) susceptibility or tolerance to different doses of aluminum added to the soil at nursery level. The experiment was established in two stages, the first one using doses of 0, 100, 300, 500 µM of AlCl<sub>3</sub>. In the second stage the aluminum doses were increased to 0, 500, 1000, 2000 µM of AlCl<sub>3</sub> with a pH 7 and a corrected pH 4,3. In the first stage, 50 ml of AlCl<sub>3</sub> was added twice per week to each plant during 120 days (17 weeks), while, in the second stage plants were immersed into a solution rich in this metal, allowing its absorption by capillarity. All the studied variables as plant height, stem diameter, fresh and dry weight of both the aerial and root parts, and the root length showed significant differences in both the simple effects and the interaction genotype x solution, except for the seed germination which was not affected by this metal. Coffee genotypes which showed a greater adaptation to the stress condition caused by aluminum were Mondo Novo rojo, Typica Amarillo, L3 and L4 (INIA 01), INIA 10, whereas Murta, Laurina, Canephora (P3), and a Salvadoran hybrid were the most susceptible ones to aluminum.

**Key words:** Coffee, Aluminum, Tolerance, Genotypes.

**PB 214**

**MUTATION LAURINA INDUCES BLUE LIGHT HYPERSENSITIVITY IN COFFEA ARABICA**

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*Coffea arabica* ‘Laurina’ is a natural mutant of *Coffea arabica* ‘Bourbon’ and is commercially known as ‘Bourbon pointu’. The *laurina* mutation leads to pleiotropic effects including dwarfism. Comparison between seedlings growing at daylight or darkness showed clearly that size difference of hypocotyls between ‘Bourbon’ and ‘Bourbon pointu’ disappeared in darkness. Expression of some genes related to the light as phytochromes A and B, cryptochrome 1, gigantea, etc. and to cell elongation and division was estimated in cotyledons, hypocotyls and roots of these seedlings, using Q-PCR. The main result concerned an overexpression of the blue light receptor – the cryptochrome 1 - in all aerial organs of ‘Bourbon pointu’ in daylight-growing conditions. In addition, seedlings obtained under blue light conditions showed a more pronounced dwarfism of their hypocotyls.

**PB 215**

**GENETIC DIVERSITY ASSESSMENT IN INDONESIAN COFFEA CANEOPHORA COLLECTION USING SSR MARKERS.**

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*Coffea canephora* which is one of the two most important commercial coffee species is cultivated in Indonesia for more than 100 years . First accessions were introduced in Indonesia in 1900 with a group of 150 plants originated from Belgian Congo. These plants were used to start a collection which was achieved in two main phases of introduction with coffee trees originated from various countries of Africa. The first phase of the collection occurred during the period of 1905-1909, and the second phase between 1914-1919. After, the collection has been regularly enriched with accessions mainly coming from local selection to achieve the actual number of 1800 accessions. The collection was used for selection and breeding program but its genetic diversity was not evaluated. This aspect is becoming a limitation for the optimized utilization of the collection. The genetic diversity of the Indonesian *C. canephora* collection was studied using 19 microsatellite (SSR) markers. A first set of 270 accessions were analyzed and classified mainly as Congolese accessions with 10% duplicates. A high genetic variability is detected with a range of heterozygosity level from 5 to 89%. The Congolese type represents the majority of cultivated coffee trees in Indonesia because of its better local environmental adaptation. There are some evidences that the selection focused mainly on this group because of farmers and breeder preference. The study will help to elaborate the best strategy to manage the genetic diversity to be maintained in consideration of genetic and phenotypic data. Results will also be used to guide the breeding program with the identification of *C. canephora* groups and sub-groups in the collection and a better usage of the total genetic diversity.

Considering the first results obtained in the study and their importance for the national program of coffee research, the evaluation will be extended to the whole Indonesian *C. canephora* collection.

## PB 216

BIOLOGY AND LIFE TABLE OF THE PHYTOSEIID MITE  
*Ricoseius loxocheles* De Leon FEEDING ON COFFEE RUST  
FUNGUS (*Hemileia vastatrix*)

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Coffee crops have economic losses with pests and diseases. Among them, the herbivore mites deserve special attention due to the reducing photosynthetic area caused on the leaves. Predatory mites from the Phytoseiidae family normally control herbivore mites. Besides of mite damages, some pathogens also attack coffee plants, specially the coffee leaf rust fungus, *Hemileia vastatrix* (Uredinales). This pathogen can cause yield losses of 30% in some varieties of *C. arabica*. Within the Phytoseiidae family that is composed by carnivorous and pollen-feeding mites, we surveyed in the field the species *Ricoseius loxocheles* (De Leon) (Acari: Phytoseiidae) on the necrosis area caused by coffee leaf rust during its reproductive phase. Searching in the literature showed that there is poor information related to its development and biological parameters. So, this study was done to assess the development, survivorship and reproduction parameters of *R. loxocheles* feeding on coffee rust fungus under laboratory conditions at temperature of  $25 \pm 1^\circ\text{C}$ ,  $60 \pm 10\%$  RH and at 12:12 light:dark cycle. The results showed that the incubation period of the eggs was 2.96 days in average and their viability was around 88.9%. This period was the longest phase of the immature stage of *R. loxocheles*. The development period of larva, protonymph, deutonymph and egg to adult was 1.96; 2.09; 1.80 and 8.88 days, respectively. The survival rate of the individuals varied depending the developmental stage. The highest mortality rate was observed in protonymphs (13.04%) and the survival from egg to adult was 70.37%. The sex ratio observed was 85.9%. The female longevity was 19.59 days and the pre-oviposition and the post-oviposition were 3.59 and 3.05 days, respectively. The amount of eggs per female per day was 0.76. The intrinsic rate of increase ( $r_m$ ) was 0.092 (0.091-0.092) females/female/day and the finite capacity for increase ( $\lambda$ ) was 1.09. Net reproductive rate ( $R_o$ ) was 5.729 (5.665-5.793) and the average duration of each generation ( $T$ ) was 18.90 days. The number of offspring produced per female ( $mx$ ) reached a peak on the 13<sup>th</sup> day of adulthood (1.06) and decreased to reach zero at the 23<sup>th</sup> day. The population has potential to double every 7.63 days. Our results indicate that *R. loxocheles* is able to feed and complete their development on coffee rust fungus. Moreover, this species deserves more studies to clarify its relationship with the rust fungus and the possible dissemination of the disease. Additionally, as member of a predatory family it is necessary to investigate if this species acts also as a predator.

## PB 217

SCREENING OF MULTIPLE RESISTANT COFFEE TREES TO *MEOLODOGYNE* spp

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Root-knot nematodes are considered as limiting factors for coffee production word wide, and therefore, the Instituto Agronômico has greatly intensified researches aiming the achievement of nematode resistant coffee cultivars, notably to *Meloidogyne incognita* and *M. paranaensis*. These nematodes cause severe damages to coffee, which could limit the economic activity of infested crops or prevent the introduction of new coffee plantations in soils contaminated by them. The Use of resistant cultivars has been considered the most efficient method among several techniques of management of nematode parasites, due to its economical and environmental safety.

This work aims to select *Coffea canephora* clones with multiple resistance to *M. exigua*, *M. incognita* and *M. paranaensis*, as well as clones of wild accessions of *C. arabica* and cultivar Icatu Vermelho IAC 925, both resistant to *M. paranaensis*, now considered the most pathogenic and aggressive species to coffee plants. Currently, resistance of wild accessions of *C. arabica* from Ethiopia to *M. paranaensis* is being evaluated under controlled conditions. Therefore, clones obtained by cutting and sexual progenies, with 4 pairs of leaves, were inoculated with the nematodes, grown in a greenhouse for 90 days, and evaluated for parameters of parasite reproduction and plant development.

This experiment aims to get information about the resistance of *C. arabica* to *M. paranaensis* in order to select resistant coffee trees for later use in hybridizations, transferring this characteristics for the current cultivars, enabling in the future, planting resistant ungrafted cultivars in areas where nematodes are a limiting factor for coffee production.

Clones obtained through direct somatic embryogenesis and also sexual progenies of Icatu Vermelho IAC 925 coffee trees selected in *M. paranaensis* infested areas were evaluated to confirm the nematode resistance observed under field conditions. This is necessary, owing the material interspecific origin that causes high outcrossing rate and consequently segregation of the resistance trait.

In subsequent experiments, clones of *C. canephora* accessions selected at *M. paranaensis* infested areas and in the *Coffea* germplasm bank from Instituto Agronômico, will be evaluated under controlled conditions to confirm the resistance to *M. paranaensis*. The response to other populations of *Meloidogyne* will also be assessed in order to select *C. canephora* plants with multiple resistance to *M. paranaensis*, *M. incognita* and *M. exigua*. In view of the occurrence of mixed nematodes populations in coffee regions, this work is important to reduce the range of cultivars with specific resistance, resulting in savings of time and money in breeding programs.

**PB 218****AGGRESSIVENESS OF *Pseudomonas syringae* pv. *garcae* STRAINS  
IN *Coffea arabica* CVS. MUNDO NOVO AND BOURBON AMARELO**

**RODRIGUES, Lucas M.R.\*, COMPARONI, Renata\*\*, ALMEIDA, Irene M.G.\*\*, PATRICIO, Flávia R.A.\*\*, BERIAM, Luis O.S.\*\*, GUERREIRO FILHO, Oliveira\***.

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Bacterial halo blight of coffee frequently was detected at nurses and fields in Brazil, mainly in São Paulo and Minas Gerais States, occurring with high severity in crops submitted to wind actions and high pluviometric index, factors that promote the disease dissemination. The increasing incidence of the pathogen studies are carrying to effective control of the disease. In this work we tested the aggressiveness of nineteen bacterial strains, from of main Brazil coffee producing regions, versus coffee seedlings of cultivars Mundo Novo IAC 376-4 (MN) and Bourbon Amarelo IAC J-30 (BA). The experiments were carried out in greenhouse from January to March 2012. Bacterial strains were obtained from the Phytobacteria Culture Collection of the Biological Institute (IBSBF), Campinas – São Paulo, Brazil. Strains were reactivated and suspended in saline solution (0,85% NaCl) resulting in a bacterial suspension to approximately  $3 \times 10^8$  UFC.mL<sup>-1</sup> of Marc-Farland scale. In the first experiment three leaves from plants of MN cultivar were inoculated by puncture d using an hypodermic needle embedded in bacterial inoculums. Aggressiveness evaluation was realized by measuring the diameter of each lesion, at 21 days after inoculation (DAI). In the second experiment, four pairs of leaves from plants of BA cultivar were inoculated with the 19 bacterial strains, and also with a mixture of four of them. Evaluation was realized daily observing the initial symptoms and strains aggressiveness was assessed by measuring the diameter of lesions at 21 DAI. The observed results corroborated the literature information that young leaves are more susceptible to bacterial infection. In BA cultivar the incubation period of more virulent strains was between 5,63 and 7,68 DAI, and the latency period between 5 and 7 DAI. Most virulent strains in MN cultivar are: IBSBF 75, 65, 1293, 2212, 1664, 1197, 2511, 2840 e 3024. In BA cultivar most virulent strains are: IBSBF 65, 75, 1197, 1293, 1372, 1664, 2511, 2840, 3024, and the mixture of strains IBSBF 75, 1197, 1293 and 3024.

**PB 219**
**NMR BIOMARKERS FOR RESISTANCE TO THE LEAF MINER IN COFFEE PLANTS BY NMR**
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Considering the importance of the coffee culture to brazilian economy, the development of techniques that allow for a greater prospecting of the profits is becoming more and more necessary, either through the reduction of production costs or through aggregation of value to the final product.. In this sense, a great effort has been undertaken in order to improve the coffee production efficiency, especially regarding plant health problems (Guerreiro-Filho, 2006), among which the leaf miner stands out as the principal. Once coffee is a perennial species with a long reproductive cycle, time and resources needed for selection of new cultivars are considerable. One strategy to shorten the selection period and reduce costs of agronomic experimentation is the early selection through biomarkers identification in the form of small cells. This strategy allows the identification of insect-resistant coffee plants during the initial growth and ensuring that progeny essays will be installed only with previously selected resistant plants. Therefore, the objective of this work was to identify secondary metabolites through proton spectroscopy ( $^1\text{H}$  NMR) capable to distinguish resistant (R) or susceptible (S) plants to the leaf miner. For that, coffee plants from a segregating progeny belonging to the  $F_2\text{RC}_5$  generation were classified regarding the resistance level according to the point scale established by Ramiro et al (2004), and then selected for metabolic analysis by  $^1\text{H}$  NMR performed using aqueous extracts (Gomes-Cadenas et al, 2002, adapted). The resulting metabolites profiles were evaluated through variance analysis . . This analysis revealed that only the myo-inositol compound was statistically distinguishable between the groups R and S, occurring in greater concentration in susceptible plants (Table 1). Therefore, myo-inositol may be considered a potential candidate as biomarker for the early identification of plants resistant or susceptible to the leaf miner .

**Table 1-** Variance analysis of identified metabolites in non-infested plants

Metabolite	Calculated F	Probability (P)	Average	
			Resistant	Susceptible
Alanine	1,86	0,20	0,06 a	0,07 a
Asparagine	0,18	0,67	1,05 a	0,93 a
Aspartate	0,99	0,34	0,10 a	0,12 a
Malate	1,51	0,24	0,81 a	1,03 a
Sucrose	0,26	0,62	0,79 a	0,83 a
Theophylline	1,72	0,21	0,16 a	0,14 a
Trigonelline	0,00	0,97	0,33 a	0,33 a
X	2,18	0,16	1,62 a	1,35 a
Myo-inositol	4,57	0,05	0,15 b	0,19 a
Gluconate	2,62	0,13	0,43 a	0,30 a

Averages followed by the same letter do not differ statistically

PB 220

**SELECTION OF COFFEE PLANTS RESISTANT TO BROWN EYE SPOT:  
GENETIC VARIABILITY AND INFLUENCE OF THE NUTRITIONAL  
CONDITION ON THE EXPRESSION OF RESISTANCE TO THE PATHOGEN\*\*\*\*.**

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Mirian P.\*\*; MARTINATI, Juliana\*, FAZUOLI, Luiz Carlos\*, GUERREIRO FILHO, Oliveiro\*.**

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Brown eye spot is an important coffee disease, present in all regions where coffee is grown in Brazil. The productivity and quality of coffee beverage can be severely reduced by the disease, especially in the Cerrado region, where the coffee crop is expanding, and also in irrigated areas. The severity of the disease can be enhanced by N and K deficiencies. Resistant cultivars can be a valuable tool for the management of the disease, however few studies to evaluate sources of resistance to be employed in breeding programs of *Coffea* in Brazil are available. Little is known about the behavior of resistant and susceptible materials when submitted to N and K deficiencies. In the first part of this study the resistance to brown eye spot was evaluated in advanced progenies from the IAC Coffee Breeding Program , which included progenies IAC 5028 L95 C124 and IAC 5026 L95 C108 (F7 of crosses between the *C. arabica* cultivars Catuaí Vermelho IAC 81 and BA10, with resistance to coffee rust) and RC<sub>1</sub> H20406 (P<sub>1</sub>, IAC 81 x F<sub>1</sub>, H8105-7). Initially the best conditions for inoculations and assessment of the disease were determined. The concentration of  $5 \times 10^4$  conidia of *C. coffeicola* mL<sup>-1</sup> and seedlings containing seven pairs of leaves resulted in the highest levels of incidence and severity of the disease and were employed in the subsequent experiments. The progenies IAC 5028 L95 C124 and IAC 5026 L95 C108 showed less incidence and severity of the disease than the cultivars Tupi IAC 1669-33, Catuaí Vermelho IAC 144, Obatã 1669-20, Mundo Novo, Ouro Verde and Bourbon Amarelo IAC J19. The progeny RC<sub>1</sub> H20406 (P<sub>1</sub>, IAC 81 x F<sub>1</sub>, H8105-7) was also very resistant to brown eye spot. The most resistant material of the previous experiments, progeny IAC 5028 L95 C124, and the very susceptible cultivar Bourbon Amarelo IAC J19 are being tested in hydroponic systems with solutions deficient or not in N and K to evaluate the molecular expression of defense genes involved in the resistance to brown eye spot and of genes involved in the transport and regulation of N and K ions.

**PB 221**

**MICROSSATELLITE FOR FINGERPRINTING *Coffea arabica* CLONES**

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Molecular markers can contribute to traditional breeding programs during decision making steps. For instance, they can be used to identify possible mixtures among genotypes, either elite or commercial material during final steps for legal registration.. The objective of this study was to use polymorphic microsatellite markers to differentiate Arabica coffee clones with potential value for intellectual protection and commercialization. Clones obtained from somatic embryogenesis were resistant to the nematode *Meloidogyne paranaensis* or to the leaf rust caused by *Hemileia vastatrix*. In the nursery, 900 seedlings with two or three pairs of leaves were evaluated after mixtures of seedlings from both clones were observed. Morphological characteristics, the color of seedling shoot and sensitivity of PCR amplification were considered to obtain bulks with 15 individuals. DNA samples were analyzed in bulks by 24 EST-SSR obtained from the Coffe EST Genome Database and were compared with the typical variety pattern. By this screening, LEG9 was identified as a polymorphic locus. It could be observed that 47% of the bulks had neither an individual contaminant. Moreover, each one of the remaining bulks had at least one individual mixed. In this work the EST-SSR allowed the identification of mixtures of clones resistant either to the nematode or to leaf rust.

**PB 222****GENETIC DIVERGENCE BETWEEN MARAGOGIPE ACCESS TO THE ACTIVE GERMOPLASM BANK OF COFFEE OF MINAS GERAIS STATE\***

**GUEDES, Janine M.<sup>1</sup>, VILELA, Diego J. M.<sup>1</sup>, REZENDE, Juliana C.<sup>2</sup>, CARVALHO, Samuel P.<sup>1</sup>, PEREIRA, Antônio A.<sup>2</sup>, SILVA, Felipe L<sup>2</sup>, OLIVEIRA, Antônio C.B.<sup>3</sup>, MENDONÇA, Edleyne R.<sup>4</sup>, SAMPAIO, Sara M.<sup>4</sup>,**

\* Financial support: Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Secretaria da Ciência e Tecnologia, Instituto Nacional de Ciência e Tecnologia do Café – INCT CAFÉ; <sup>1</sup>Universidade Federal de Lavras, Lavras, MG, Brasil, <sup>2</sup>Empresa de Pesquisa Agropecuária de Minas Gerais, MG, Brasil, <sup>3</sup>Empresa Brasileira de Pesquisa Agropecuária, Viçosa, MG, Brasil, <sup>4</sup>Bolsita FAPEMIG, MG, Brasil.

Maragogipe coffee genotypes are characterized by a more rustic plant, with size, flowers, fruits and seeds in higher dimensions, besides having good quality of the beverage, which is attracting great interest from breeders for future crossings. One way to optimize these crossings is the study of diversity and genetic divergence that generate benefits to predict the genetic gains and the possible success in breeding programs. Thus, this study aimed to identify the genetic divergence among the group of coffee Maragogipe located in the Active Germoplasm Bank of Coffee in Minas Gerais State, by using multivariate analysis. Twenty-seven features were analyzed, using the Tocher group, UPGMA method (Unweighted Pair-Group Method Using Arithmetic Averages) and canonical variables analysis. The cluster analysis by the Tocher method and the UPGMA method separated the 12 accessions in seven groups. Cruz et al. (2004) not suggest the involvement of individuals of the same pattern of dissimilarity in the crossings, so as not to restrict the genetic variability and thus avoid negative effects on the gains to be obtained for selection. Thus, these accesses in clusters were shown to be far more dissimilar to each other and can be regarded as promising artificial selection. Three features contributed with 43.20% of genetic diversity, according to the method of Singh (1981), namely: the intensity of leaf curl (10.19%), number of inflorescences per leaf axil (10.31%) and average productivity (sc/ha) for the biennium 2009/2010 (22.70%). Measures of genetics dissimilarity, calculated from the Mahalanobis distance showed a high magnitude (0.52 to 84.9), indicating the presence of wide genetic variability among accessions. It was observed that, by virtue of the first three canonical variables explain more than 90% of the total set of characteristics analyzed could satisfactorily explain the variability manifested among the analyzed accessions, corroborating the results found previously.

Cruz CD and Regazzi AJ (2004) **Modelos biométricos aplicados ao melhoramento genético**. Editora UFV, Viçosa, 480 p.

Singh (1981) The relative importance of characters affecting genetic divergence. **The Indian Journal of Genetic and Plant Breeding** 41: 237-245.

**PB 223**
**MULTIVARIATE ANALYSIS IN BOURBON ACCESS OF ACTIVE GERMPLASM BANK OF COFFEE OF MINAS GERAIS STATE\***

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\*Financial support: Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Secretaria da Ciência e Tecnologia, Instituto Nacional de Ciência e Tecnologia do Café – INCT CAFÉ; <sup>1</sup>Universidade Federal de Lavras, Lavras, MG, Brasil, <sup>2</sup>Empresa de Pesquisa Agropecuária de Minas Gerais, MG, Brasil,

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This work aimed to study the Bourbon coffee accesses the Active Germplasm Bank of Minas Gerais by means of multivariate analysis. We analyzed 27 characteristics of 126 accessions of Bourbon, using the Tocher grouping. The group I presented, 57 access genetically similar, and the second group, also showed a greater number of similar access, being characterized by having 27 access, suggesting that these are part of the same heterotic group. Two groups had six access in each, the group III and IV, and two had four access each, the group IV and V group. Agronomic characters of these different groups are expected 6 genotypes, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 e 27, because they have formed isolated groups. The formation of these groups represents valuable information on the choice of parents in breeding programs, for the new hybrid populations to be established should be based on the magnitude of their distances and the potential of the parents alone.

TABLE 1 Groups formed according to the method of Tocher based on the distance ( $D^2$ ) of Mahalanobis, of the 126 accessions evaluated the Bourbon Active Germplasm Bank of Minas Gerais

Groups	Access
1	74 78 71 66 42 86 59 83 44 72 81 40 50 60 58 67 61 55 76 64 65 84 45 122 68 125 112 121 105 115 12 97 70 79 63 82 111 62 51 106 15 124 116 52 75 43 87 93 101 117 28 73 33 119 80 89 16
2	9 21 29 39 34 23 17 20 24 25 30 26 36 22 4 19 6 37 13 11
3	47 107 31 120 103 92
4	108 109 99 91
5	10 27 88 1
6	94 126 110 95 85 38
7	7 41 49
8	18 48
9	53 104 96
10	57 69
11	2 77
12	100 123
13	56
14	94
15	114
16	54
17	46
18	118
19	102
20	8
21	35
22	3
23	113
24	90
25	5
26	14
27	32

**PB 224**

**CHARACTERIZATION, CLONING AND SEQUENCING OF A PUTATIVE METALLOTHIONEIN-LIKE PROTEIN IN *Coffea Arabica*.**

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Metallothioneins (MTs) are proteins of low molecular weight, part of a cysteine-rich superfamily. The cysteine domains have great affinity to metal ions, and have shown to associate more commonly to Zn<sup>2+</sup> and Cu<sup>+</sup>. Specifically when referring to plants MTs, it is preferred to use the term *MT-like* once most of them are inferred from DNA sequences derived from different species. The expression of MTs can be induced either by the presence of metal ions or by chemical and physiological stresses and although they are proteins known to be part in the processes of metal homeostasis and heavy metal detoxification, the precise function is still the subject of debates. Many recent researches have reported the existence of MTs in several different organisms such as cyanobacteria, plants and animals, what shows a high conservation of certain domains in this group of proteins and indicate its importance throughout the evolutionary pathway of many species. In our search in the database of coffee Expressed Sequence Tags (CAFEST) using keywords and sequences of known metallothionein-like proteins, we obtained 25 EST-contigs. These sequences, that showed a reliable similarity, were clusterized and annotated. Multiple alignments were performed, comprising the sequences found in this work and sequences of metallothioneins from other species. The phylogeny was assessed by phylogenetic trees constructed by the MEGA4 software and the expression profile was assessed by *in silico* Northerns performed by the Cluster and visualized by the TreeView program. The expression of the ESTs occurred more often in libraries of seedling and leaves treated with arachidonic acid. However, the MTs showed a wide expression profile, being detected in many tissues. These results indicate the probable involvement of coffee MTs in different phases of the plant development. Based in the bioinformatics analysis, we then selected two contigs that showed a complete metallothionein conserved domain and that were expressed in leaves libraries – the sample tissue used for extracting the DNA and RNA. PCR primers were designed and thus the coding sequences were isolated from both cDNA and genomic DNA. The fragments were then cloned into pGEM-T vector and sequenced in MEGABase (Pharmacia). For the cDNA, the sequence obtained showed a high similarity with the sequence that resulted from the clusterization. However, in clone with DNA insert, we could not obtain a complete sequence, what could be explained by the size of the predicted fragment (around 800 bp). So, another primer design is need in order to get the gene full sequence (including introns).

Financial support: FAPEMIG, CNPq, INCT/Café and CAPES

## PB 225

DETERMINING FLOWER CHARACTERISTICS ON CROSSING PROGENIES  
OF CONGOLESE CLONES WITH AN HYBRID OF CONGOLESE AND  
GUINEAN CLONES OF ROBUSTA COFFEE (*Coffea canephora*)**NUGROHO Dwi\*, PRIYONO\*, SUMIRAT Ucu\*, MAWARDI Surip\*, CROUZILLAT, Dominique\*\*.**

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Flowering plays an important role in determining yield of Robusta coffee. Flower development started from the initiation of flower bud, followed by candle stages and blossoming stage. Flower abnormality evidence oftenly occurs during the blossoming stage, mainly formation of star flowers, due to unfavorable environment such as excess of rainfall and drought stress. In this study the genetic background, especially QTLs determining flowering characteristics, were identified. A set of three crossing Robusta progenies using three parental clones namely BP 409 and BP 961 (belonged to Congolais group) as well as Q 121 (an hybrid of Congolais and Guinean) were used in this experiment.

This study successfully identified 12 QTLs related to flowering characteristics where located at seven linkage groups. These QTLs consisted of (1) two QTLs with LOD score of 3,4 and 3,6 associate to number of flowers located at linkage groups of G and H; (2) five QTLs with LOD score from 3,3 to 4,2 associate to number of normal flowers located at linkage groups of A, C and D; and (3) five QTLs with LOD score from 3,0 to 5,4 associate to number of star flowers located at linkage groups of D, E, F and G.

An interesting evidence was found in this study namely QTLs associate to flowering characteristics absence on hybrid population of BP 409 x BP 961 (both belonged to Congolais group), but these were presence on the hybrid progenies of BP 409 x Q 121 and BP 961 x Q 121.

These results can be a first step for molecular breeding on Robusta coffee mainly in order to improve potential suitable characteristics such as total number of flowers and number of normal flowers as well to reduce adverse characteristics such as number of star flowers.

**Key words:** *Coffea canephora*, QTLs, flowering abnormality.

## PB 226

HETEROSESIS AND DROUGHT TOLERANCE OF F1 HYBRIDS  
BETWEEN THE COFFEE CATUAÍ VERMELHO AND  
INTRODUCTIONS GEISHA AND WUSH-WUSH OF *Coffea arabica***FAZUOLI, Luiz C.\*, BRAGHINI, Masako T.\* , SILVAROLLA, Maria B.\* , GUERREIRO FILHO, O\*.**

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The Instituto Agronômico de Campinas, received in 1953, the introduction IAC 1137, Geisha, originally from Africa (Ethiopia) and from the United States and IAC 1521, BE-5 (Wush-Wush) from Ethiopia and from CATIE, Costa Rica in 1967. Were selected some plants such introductions that were crossed in 1970 with the 'Catuaí Vermelho' of *Coffea arabica*. The F1 hybrids obtained (H8089 and H8114) were planted in experiment EP 131 in Campinas, SP, Brazil. The aim of this study was to evaluate the production and drought tolerance of coffee hybrids for cultivar control Catuaí Vermelho. In 16 harvests the average production of the F1 H8089 (Catuaí Vermelho x IAC 1137-5) was 4.995 grams of cherries / tree / year, the F1 H8114 (Catuaí Vermelho x IAC 1521-2) was 4.256 grams and the control cv. Catuaí Vermelho produced 3.017 g / plant / year. Heterosis on the

production of F1 H8089 compared to the 'Catuaí Vermelho' was 65.5% and 41.1% in the hybrid H8114. The drought tolerance was measured in years in the field of water stress, by using the scale of points 1-10, turgidity index (IT), wherein a plant to leaves with withered plant, and 10 for sheets with turgid. The range of variation averaged 3.5 to 6.3 for the hybrid coffee H8089, H8114 to 3.0 to 6.7 and 3.6 to 6.3 for 'Catuaí Vermelho'. The plant most productive H8089 gave 7397 g of coffee cherries / year, of H8114 produced 8164 g and the best plant of control 'Catuaí Vermelho' 4363 g. In 1994 these three plants showed values IT, 9.0, 8.0 and 8.0 points, respectively. It was found, however, drought tolerance in both hybrids and 'Catuaí Vermelho'.

## PB 227

SOMATIC EMBRYOGENESIS IN HYBRIDS OF *Coffea arabica*

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The current coffee market has great demand for hybrids of *Coffea arabica* L. that due to the heterosis they may have special features, like production, resistance to biotic and abiotic factors or quality of drinking. But the multiplication of these hybrids should be vegetative because the plants from the germination of seeds lose the special characteristics due to the genetic segregation. Somatic embryogenesis allows multiplication of hybrids of arabica. Somatic embryos can be obtained by indirect somatic embryogenesis which consists of two phases, the callogenesis and the formation of embryos or via direct that occurs in one step. The objective of this study was to characterize the ability to direct and indirect somatic embryogenesis in three hybrids of *C. arabica* with high quality beverage. The study was conducted at the Centro de Análise e Pesquisa Tecnológica do Agronegócio do Café 'Alcides Carvalho', of Instituto Agronômico de Campinas, SP. We used explants from leaves collected from adult plants of *C. arabica* hybrids H8105 (Catuai Vermelho x BA10), H8427 (Acaíá x BA10) and H8089 (Catuaí Vermelho x Geisha) and the cv Mundo Novo IAC 376-4, used as control, kept under field conditions. It was used MS culture medium, solidified with 5 g/L agar, pH 5.8, autoclaved for 20 minutes at 121 °C and 1.5 atm. On the induction of indirect via, for the callogenesis it was used 2.4 dichlorofenoacetic acid (2.5 µM) and kinetin (5 µM) while for the embryogenesis, the naphthaleneacetic acid (0.5 µM) and kinetin (2.5 µM). For the direct pathway, it was used 2-isopentenyladenine (10 µM). Each treatment consisted of 20 flasks, with two explants per flask, maintained in continuous dark at 25 °C and evaluated every 30 days: presence of callus or embryogenic structures, number of sides of the explant with formation of callus or embryogenic structures, coloring of the explants, the estimated size of callus or the embryogenic structures and number of somatic embryos. Until now, the results indicated that the indirect pathway in the explants of all genotypes callus rate exceeding 80%. The calluses of cv Mundo Novo and genotypes H8105 and H8427 were larger than those of H8089, respectively, 7.0, 7.4, 7.2 and 5.2 mm in size, at 90 days of conducting of the experiment. On the other hand, the direct pathway, the cv Mundo Novo and the hybrids H8105 and H8089 were respectively 72.5, 63.2 and 83.3% of explants with embryogenic structures formation while H84273 was 56.3%.

## PB 228

## EVALUATION OF CELL SUSPENSIONS OF COFFEA ARABICA CV. CATIGUA, BY GROWTH CURVE MEASUREMENTS

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Cell suspension cultures (CSC) is an in vitro system that can be used as a tool for various studies in *Coffea arabica*. They can be used in experiments involving mutant selection, mass propagation, protoplast isolation, gene transfer and cell biology. However the success of these applications depends on the quality (amount of potentially embryogenic cells) of the suspension used which is affected by the appropriate supply of nutrients and plant hormones during the multiplication phase. The optimum parameters for the maintenance of cell suspensions cultures must be obtained for each species and even for each genotype. The objective of this work was to study the growth of CSC obtained from *C. arabica* cv. Catigua MG2, in order to define the right parameters necessary to maintain the quality of this material. The cell suspension cultures were initiated from embryogenic callus obtained from inoculated leaves, with density 16 g/l, incubated at 27° C on a rotary shaker (100 rpm), kept in the dark. Every fortnight, the sedimented cell volume (SCV) from the suspension cultures was measured and used as a non-destructive parameter for quantifying the proliferation. At the same time, one-sixth of the culture medium was refreshed. It was obtained the absolute growth at the end of 60 days and relative growth (or growth rate, in percentage) between each measurement. From the results, it was observed that there was absolute growth at an exponential rate until 45º days, stable growth between 45º and 55º days, decreasing until the 65º day and decreasing sharply until 75º day. This indicates that replacement of one-sixth of the culture medium volume after 45 days is sufficient to maintain exponential growth rate of CSC of *C. arabica* cv. Catiguá.

Supported by Finep, FAPEMIG, CAPES e CNPq.

## PB 229

## A COMPARATIVE PROTEOMIC STUDY OF COFFEA ARABICA CV. BOURBON GROWN AT DIFFERENT ALTITUDES IN BRAZIL.

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Genotype and environment are the most important factors that contribute to defining the final quality of coffee beverage. Carbohydrates, enzymes, lipids and proteins have been associated with changes in flavor and aroma. This work was carried out to study the differential proteomic profile from bean of Bourbon cultivars, grown in two environments, in order to relate them with the quality of beverage. These conditions were evaluated by proteomic analysis using bi-dimensional electrophoresis 2D-PAGE. Gels were stained with Commassie Blue G-250 and analyzed using the software ImageMaster 2D Platinum 5.0 (Amersham). In this study, analysis demonstrated that there are differences in the protein profile of the same genotype grown in different environments, although the same cultural practices, harvest and postharvest we used. We identified changes in expression of multiple proteins. These proteins will be sequenced and characterized by MALDI-TOF/TOF MS. We hope that some proteins can be correlated with some biochemical changes and be used as a molecular marker to coffee beverage quality.

Supported by FINEP, CAPES, CNPq e FAPEMIG.

## PB 230

ASSESSMENT OF INDIRECT SOMATIC EMBRYOGENESIS  
FROM LEAVES OF *COFFEA ARABICA* PLANTS GROWN IN  
VITRO AND IN GREEN HOUSE.

LIVRAMENTO, Kalynka Gabriella do\*; CASTRO E ANDRADE, Jéssica\*; TORRES, Luana Ferreira\*;  
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The study of the propagation of *Coffea arabica* has increased in recent years due to increasing investment in research related to genetic transformation of this species, since it allows to produce cultivars with desirable agronomic characteristics. To obtain genetically transformed plants, the tissue culture should be improved to enable cloning of the full-scale in vitro material. On this work we evaluated the combination of two methods described to obtain yellow friable callus of *C. arabica* (van Boxtel & Berthouly (1996) and Texeira et al (2004)), and two sources of explants (leaf from in vitro plantlets and from plants cultivated in green house). The results showed no significant differences between treatments. It was observed the formation of three different types of callus, among them the yellow friable callus. Only the quality of yellow callus was assessed by histological analysis. The samples were fixed in FAA 50 and preserved in alcohol 70. The 3 µm longitudinal sections of the material were obtained in rotational microtome (with the material included in historesine). The sections were stained with Toluidine blue and Lugol and observed by conventional light microscopy. The yellow callus obtained corresponded to a highly homogeneous tissue mainly comprised of small cell aggregates similar to proembryogenic masses (PEMs). Cells present on this type of callus exhibit numerous small starch grains and visible mitosis stages, suggesting rapid divisions and growth. Those characteristics are typically observed in embryogenic cells. These analyzes allows the choice of highly competent embryogenic material to genetic transformation experiments, whereas they could also be used as structural markers to select potentially embryogenic explants cultures.

Supported by FINEP, FAPEMIG, CAPES e CNPq.

## PB 231

HISTOLOGICAL ANALYSIS OF EMBRYOGENIC SECTORS FORMED  
ON THE SAME LEAF POSITION IN *COFFEA ARABICA*.

LIVRAMENTO, Kalynka Gabriella do\*; SILVA, Anderson Tadeu\*; PÁDUA, Marlúcia Souza\*; TORRES,  
Luana Ferreira\*; BARBOSA, Filipe Vaneli\*; CASTRO E ANDRADE, Jéssica\*; PAIVA, Luciano Vilela\*.

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Obtaining large scale of somatic embryos of *Coffea arabica* L. in vitro is an important event for breeding programs and the success of this step is linked with the quality of potential embryogenic calli (EC). According with some authors, one or more embryogenic callus can form on the same leaf explant position. In this work, histological analyzes were used in order to evaluate the quality of the cells obtained from three subsequent formed EC, all extracted from the same leaf position. The embryogenic callus from three different genotype of *C. arabica* (Catuai, Catuai e Bourbon), were fixed in FAA 50 and preserved in alcohol 70. Later on, they were fixed in historesine and cutted in 5 µm longitudinal sections using rotational microtome. The sections were stained with Toluidine blue and Lugol and observed by conventional light microscopy. Histological analysis didn't demonstrate a change in the quality of embryogenic callus tissues, independing of the genotype and the order of callus formation. All the embryogenic callus analysed, were made by small cell aggregates, similar to proembryogenic masses (PEM), with small and isodiametric cells exhibiting several small starch grains. These results indicate that PEMs of *C. arabica* obtained, can be used as a competent target tissue for coffee genetic transformation.

Supported by FINEP, FAPEMIG, CAPES e CNPq.

## PB 232

EXPRESSION OF *bZIP19* UNDER CONTROL OF THE ZINC DEFICIENCY RESPONSIVE *ZIP4* PROMOTER IN COFFEE (*Coffea arabica* L.)**HENRIQUES, Ariadne\***, **CHALFUN-JUNIOR, Antonio\***, **AARTS, Mark\*\***

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Coffee is one of the most valuable agricultural export commodities. The expansion of coffee crops to less fertile soils has led to an increase of the zinc deficiency problem, which compromises coffee growth and production. Recently two bZIP transcription factors, bZIP19 and bZIP23, were identified. They are essential for switching on the zinc deficiency response of *Arabidopsis thaliana*. Previous experiments showed that the increase of expression of *bZIP19* mediated by the promoter of the zinc deficiency responsive *ZIP4* gene is a promising strategy in enhancing *Arabidopsis* zinc deficiency tolerance. The *bZIP19* transcription factor is conserved in the plant kingdom, so the pZIP4::bZIP19 construction appears promising to test in coffee. Coffee seeds transformed with either pZIP4::bZIP19 or pDsRed-Root (control), by *A. rhizogenes* were grown in climate chamber for five months, after this time the plants were transferred to a solution containing a deficient (0.05µM ZnSO<sub>4</sub>) or sufficient zinc supply (2 µM ZnSO<sub>4</sub>) to test the zinc deficiency tolerance of the pZIP4::bZIP19 transformed coffee plants. The plants were kept under this condition for about 30 days, of which during the first two weeks the nutrient solution was refreshed once a week and thereafter twice a week. The results of this pilot project reinforce our previous findings with *Arabidopsis*. The pZIP4::bZIP19 transformed Coffee plants showed better adaptation to zinc deficiency, suggesting that this strategy may promote the development of zinc deficiency tolerant crops enabling plants growing without significant yield penalties in areas suffering from low zinc bioavailability.

Financial support: FAPEMIG, CNPq, INCT/Café and CAPES

## PB 233

PEST RESISTANCE IN WILD SPECIES OF COFFEE viz.  
*Pislanthus Travancorensis* (Wight&Arn.) & *Coffea liberica* Hiern  
(Gentianales:Rubiaceae)**SUREKHA, Kuyyalil, \*, NAIDU, Rayankula, \*\*, KURIAN, Raphael \*\*\***

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The coffee white stem borer *Xylotrechus quadripes* is currently the most damaging pest of Arabica coffee in India. Due to strict endocarpic behaviour of the larvae, pest easily escapes classical chemical treatments and pest management is currently conducted by a variety of cultural practices difficult to implement. Attempts were made to develop stem borer resistant transgenic coffee by optimizing novel Bt genes by the first two authors. But rapid adoption of transgenic crops may pose some significant risks to ecosystems as well as some economic risks to farmers and transgenic crops may not support a sustainable approach to crop production. Due to the concerns about the transgenic crops, authors trying an alternative method to develop inbuilt resistance against the stem borer in domestic coffee from gene pool of naturally resistant wild species of coffee.

Two wild varieties of coffee viz *Pislanthus travancorensis* and *Coffea liberica* or tree coffee are showing natural resistance to stem borer. Field trials as well as laboratory trials were conducted by releasing adult *X. quadripes* in nested plants and trees in both species of coffee. For the laboratory trials, cut stems were

provided and adult beetle were released in the cages .Arabica coffee stems were used for control experiment for releasing adult beetles. Artificial diet for the *X.quqdripes* was standardized first time by the authors for incorporating Bt toxins. In the same combination of artificial diet, instead of the major ingredient ie, Arabica stem powder, stem powder of *P.travancorensis* as well as in other set *C.liberica* stem powder were used to prepare the artificial diet and percentage of mortality recorded was more than 50% and there was no adult emergence, where as in Arabica stem powder used diet, less than 10% mortality and adult emergence were recorded. Hence we assume that in both species of wild coffee the plants metabolites or proteins present, which are harmful to this pest and may be the reason for resistance against this pest. Studies are underway at Kannur University. We focus on Genome wide analysis of gene expression patterns. Genes that are found to be expressed in high amounts following an attack by a pest may well involved in the plant's defence against the pest. Disease and pest resistance are desirable traits. The majority of plant disease resistance genes isolated so far encodes a predicted N-terminal nucleotide binding site (NBS) and a C-terminal stretch of leucine rich repeat (LRR).The NBS sequence of these resistance genes are characterized by the presence of up to seven conserved motifs including P-loop, Kinase-2, Kinase-3 and GPL motifs (Meyers et al 1999). Presence of these conserved motifs have facilitated the designing of degenerate oligonucleotide primers and so is helpful in the amplification and cloning of Resistance Gene Analogs (RGAs) from diverse species by PCR. The study of the chemical constituents of the cell using analytical chemistry of cultivated and resistant variety of coffee also may drive to a conclusive result.

**PB 234**

**PHYSIOLOGICAL, BIOCHEMICAL AND MOLECULAR  
RESPONSES OF *COFFEA* spp. TOWARDS TOLERANCE TO  
LOW NON-FREEZING TEMPERATURES**

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Low positive temperatures are of up most importance in tropical plant species, namely in *Coffea* spp., since it disturbs plant growth and metabolism, with impact on photosynthesis and yield. An integrated physiological, biochemical and molecular approach was used to evaluate the cold impact and the triggering of mechanisms that allow the plants to cope with this environmental constraint, particularly in what concerns the photosynthetic pathway, linked to modifications of the antioxidative system and chloroplast membrane lipids. Coffee genotypes with contrasting cold sensitivity were used and determinations were performed along a slow cold imposition (to allow acclimation) from 25/20 °C (day/night) down to 13/8 °C, after exposure to 4° C (chilling) and in the rewarming period thereafter. Cold exposure strongly affected net photosynthesis and Chl a fluorescence parameters in all genotypes, although stomatal limitations were not detected. Some genotypes revealed lower leaf loss and less deleterious effects on  $A_{max}$  and PSI activity, as well as the reinforcements of PSII activity and of the antioxidative system. That was further related to qualitative changes in chloroplast membrane lipids and to the regulation of key genes expression. Considering a broader view that integrates the results from our group, this multidisciplinary approach points to useful criteria for cold tolerance selection in coffee plants.

## PB 235

USE OF MARKER ASSISTED SELECTION AS A TOOL FOR  
EFFECTIVE AND RAPID INTROGRESSION OF THE RUST  
RESISTANCE GENE  $S_H3$  INTO COLOMBIAN ELITE CATIMORS**HERRERA, Juan Carlos, HURTADO, Ifigenia, GONZALES Laura, CORTINA, Hernando**Centro Nacional de Investigaciones de Café, CENICAFE. AP2427 Manizales, Colombia ([www.cenicafe.org](http://www.cenicafe.org)).

Experience on genetic control of phytopathological fungus in different crops including coffee trees, shows that extensive use (in time and space) of resistant varieties raise the possibilities of emergence of new races more and more virulent. Since liberation of the Colombia variety in 1985 and then the Castillo® variety and its regional components in 2005, progressive occurrence of plants with presence of rust symptoms suggest the generation of new *Hemileia vastatrix* races compatible with resistance genes (R genes) carried by these Catimor derivatives. Introgression into Colombian varieties of a new gene such as  $S_H3$  would facilitate creation of genotypes carrying new combinations of R genes which will operate in the field as a genetic barrier against predominant rust races. Recent identification of molecular markers linked to the  $S_H3$  gene issued from *C. liberica* (Mahé et al, 2008; Lashermes et al., 2010) have opened the possibility of real implementation of an strategy of marker assisted selection (MAS) in coffee breeding programs around the world. The aim of this work was to develop advanced lines (i.e. F4) recombining the  $S_H3$  along with the R genes already present in the Colombian elite genotypes and derived from the Timor Hybrid (i.e.  $S_H6$  to  $S_H9$ ). To do that, the Coffee Breeding Program of Cenicafe starts in 2010 a wide cross pollination program involving 44 élite Catimors derived from different accession of the Timor Hybrid (i.e. CIFC-1343, CIFC-832 and CIFC-2252) and some selected Arabica genotypes present in the Colombian gene bank and known as be introgressed by the  $S_H3$  gene. During first part of this project more than 130 crosses have been produced, giving as result almost 500 F1 hybrid plants. Using a MAS strategy, almost 250 F1 seedlings carrying the  $S_H3$  gene have been identified and will be transferred to the field in order to obtain F2 seeds. Once planted, the F2 families will be evaluated and selection for desirable types involving high rust resistance and vigor, elevated productivity and good bean size will be done. The F3 families derived from best F2 plants will finally be evaluated by regional adaptability and high cup quality in order to select the best F3-F4 lines. These genotypes will be used as part of composite varieties which have been the central point of the strategy used by Colombia in order to achieve a more durable resistance by maintaining a high genetic diversity against this disease.

## PB 236

DEHYDRINS ARE HIGHLY EXPRESSED IN WATER-STRESSED  
PLANTS OF TWO COFFEE SPECIES**SANTOS, Adriana B., MAZZAFERA, Paulo**

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Drought is the main limiting factor for coffee productivity. In this study, we evaluated the relationship between dehydrins (DHN) and water status in *Coffea arabica* cvs. Catuai and Mundo Novo, *C. canephora* cv. Apoatã, and a graft of Mundo Novo shoot on Apoatã root. The plants were control stressed to achieve a water potential ( $\psi_w$ ) of approximately  $-2.15 \pm 0.05$  MPa at predawn (6:00 am). Measurements of  $\psi_w$  on the preceding day (at 12:00 pm) and at predawn showed that the Arabicas had greater losses of shoot and root dry mass. Additionally, proline increased in roots and leaves of all plants, indicating stress establishment. Two DHN genes in *C. arabica* (*CaDHN1* and *CaDHN3*), three in *C. canephora* (*CcDHN1*, *CcDHN2*, and *CcDHN3*), and

one (*CrDHN1*) in *C. racemosa* were identified from an expressed sequence tag database with greater than 95% identity. Transcripts of *DHN1*, *DHN2*, and *DHN3* accumulated in roots and leaves of stressed plants and also in cell suspension cultures of Catuai stressed with PEG-8000. While *DHN1* and *DHN3* exhibited basal expression levels, *DHN2* was exclusively expressed in stressed plants. Although *DHN* genes were induced by water stress, the expression pattern of each gene was spatially (leaves and roots) and temporally (distinct stress levels) differentiated, as was the intensity of the responses among the Arabicas, Apoatã, and MN/Apoatã plants. Our results suggest a strong and causal relationship between *DHN* expression and water stress tolerance in coffee.

**PB 237****ANTHOCYANINS IN THE LEAVES OF COFFEA ARABICA:  
IDENTIFICATION AND FUNCTIONAL STUDIES**

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Excessive light can be harmful to plants and pigments such as anthocyanins may have an important role in photoprotection. The aim of this study was to determine which anthocyanins are related to the purple colouration of young leaves in *Coffea arabica* var. Purpurascens and assess their impact on photosynthesis as compared to *C. arabica* var. Catuaí, with green leaves. Two delphinidin glycosides were identified and histological cross-sections showed they were located throughout the adaxial epidermis in young leaves, disappearing as the leaves mature. Under high irradiance, the photosynthetic performance of Purpurascens leaves did not differ from that observed in leaves of the Catuaí variety, providing no evidence of an adaptive advantage under sunny conditions. To analyse the photoprotective action of anthocyanins, we evaluated the isomerisation process for chlorogenic acids (CGAs) in coffee leaves exposed to UV-B radiation. No differences were observed in the total content of phenolic compounds in either variety before or after the UV treatment; however, we observed less degradation of CGA isomers in the Purpurascens leaves and a relative increase of *cis*-5-caffeoylquinic acid, a positional isomer of one of the most abundant form of CQA in coffee leaves, *trans*-5-caffeoylquinic acid, suggesting a possible protective role for anthocyanins.

**PB 238****EXPRESSION OF GENES ASSOCIATED WITH  
MACRONUTRIENTS METABOLISM IN RESPONSE TO  
NUTRITIONAL DEFICIENCY AND LEAF-MINER INFECTON**

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The leaf-miner (*Leucoptera coffeella*) is the major coffee plague of Brazilian plantations, and damage to the plants includes leaf lesions, decrease of photosynthetic activity and defoliation. Resistant cultivars are been developed at the Agronomic Institute (IAC, Campinas/Brazil) by transferring resistant genes from *Coffea racemosa* to *C. arabica*. Although advanced populations are already available for field trials, molecular aspects underlying defense mechanism of resistant plants are not completely known. Several physiologic factors may affect the defense response of resistant coffee trees to the leaf-miner, including nutrient availability during plant growth. In this sense, evaluation of biological mechanisms associated with regulation and transport of

macronutrients during insect infection may provide insights to elucidate defense pathways. In this study, the expression profile of five genes (ANR1, Asn1, Pyr K, Calc B and SNF1), involved with transport and regulation of potassium and nitrogen in plant tissues, was evaluated in coffee seedlings submitted to limiting nutrition. Young plants from both resistant and susceptible genotypes were irrigated with solutions containing regular ( $N^+K^+$ ) or deficient ( $N^-K^-$ ) amount of macronutrients. After treatment, plants were infested with leaf-miner, and samples were collected along insect development. Gene expression was evaluated in those leaves by qRT-PCR. Differential gene expression was observed for all assessed genes in response to the nutritional stress. However, no significant differences were observed in gene expression between resistant and susceptible plants. These preliminary analyses suggest that regulation of nutrient up-take and/or transport may not play an important role during coffee defense response to leaf-miner.

PB 239

**SPECIES INTRODUCTION PROMOTES HYBRIDIZATION  
IN COFFEA VIA NICHE AND PHENOLOGY SHIFTS**

**GOMEZ, C.<sup>1</sup> DESPINOT, M.<sup>2</sup> HAMON, S.<sup>1</sup> HAMON, P.<sup>1</sup> DUBREUIL-TRANCHANT, C.<sup>1</sup> OUCKEWEN, J.<sup>1</sup>  
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Plant introduction to new areas are often associated with environmental changes which could however provide favorable conditions for certain species adaptation. In case of introduction of closely related taxa the new conditions may also affect their reproductive isolation mechanism and promote interspecific introgressive hybridization.

Three *Coffea* species, *C. canephora*, *C. liberica* ( $2n=2x=22$ ) and *C. arabica*, ( $2n=4x=44$ ) are geographically isolated in their natural habitat range, in Africa. Moreover, these species are temporally separated by different flowering phenologies. Their introduction in New Caledonia (Pacific Ocean Island) has generated a secondary contact in sympatric populations and genetic admixture has been reported.

To understand how these species faced this different environment, we applied ecological niche models to examine the climate and niche occupation associated with each species in Africa and in the introduced hybrid zone in New Caledonia. Then, to evaluate specific life history traits responses under climate change, flowering phenologies were recorded through a field survey. Hybridization and introgression between these related taxa were further characterized thanks to chloroplastic and genomic microsatellite markers.

A specific shift in precipitation regimen from native to introduced ranges impacted flowering phenology by shortening time delay between species blooming peaks. As a consequence, genetic data from backcrosses indicated widespread introgression and directional gene flows according to phenology sequences.

Introgression between these distinct species may increase the genetic diversity and generate novel genetic combinations for novel adaptations required for this new environment.

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**PB 240**

**NEW DEVELOPMENT OF MOCCADB; A GENOMIC RESOURCE FOR COMPARATIVE STUDIES AMONG THE RUBIACEAE AND DISTANTLY RELATED FAMILIES**

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The MoccaDB database (<http://moccadb.mpl.ird.fr>) is an integrated comprehensive resource for the Rubiaceae family [1]. It has been created to manage information about genomic sequences and genomic-derived markers developed on *Coffea* with cross-amplification in other Rubiaceae genera.

In the present decade, with the constant improvement in sequencing technologies, whole genome sequences of more and more plants (arabidopsis, rice, papaya, tomato, potato, grape) are available permitting extended comparative genomics studies. With implementation of new modules, MoccaDB becomes a powerful comparative resource for the plants of the Rubiaceae family and distantly related plant species with the aim to relate these species to one another using a comparative genomics approaches.

The Rubiaceae family is phylogenetically related to the Solanaceae family that contains agronomic important crop species such as potato, tomato and tobacco. Both families belong to the Euasterid I clade while grapevine (Vitaceae) belongs to the Rosid clade. Coffee and tomato separated from grapevine 125 million years ago, while coffee and tomato diverged 83-89 million years ago. These long periods of divergent evolution should have permitted the genomes to reorganize significantly.

A large set of conserved single copy genes, called Conserved Ortholog Set (COSII) have been defined *in silico* among Solanaceae species using the model plant *Arabidopsis thaliana* [3]. These COSII genes were used as markers to develop genetic maps and to perform comparative analysis among Solanaceae species and *Coffea* [1,4]. From a large set of genetically mapped COSII markers, we recently combined new macro- and microsynteny studies to evaluate the genome structure conservation between coffee, Tomato and Grapevine. In the framework of this study, we have integrated new sets of data into MoccaDB database (COS markers, genetic and physical maps). With new modules, it is possible to access information on numerous COSII genes and comparative genomic data. Users can search for markers, sequences, maps through multi-option query forms. MoccaDB includes CMap viewer and BLAST and links to related external data sources (e.g. SOL Sol Genomic Network database, NCBI Genbank and PubMed).

MoccaDB allowed us to perform the first multiple comparison between species from Asterid and Rosid clades, to examine both macro-and microsynteny relationships. 867 genetically-mapped COSII markers in coffee and tomato identified blocks of synteny with the grapevine pseudo-chromosomes, giving complex and fractioned conservation of genome macro- and micro structure between the three species (see presentation on synteny in this congress by Guyot et al.). The results of these comparative maps have made it possible to identify the orthologous counterparts among three genomes: coffee, tomato and grapevine [5].

In conclusion, we are convinced that this database will facilitate sharing of genomic and genetic information including genome sequences, allow further development of molecular breeding in coffee, and advance studies of genome evolution and comparative genomics among the Rubiaceae family and distantly related plant species.

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PB 241

DITERPENES IN *COFFEA ARABICA*: BIOCHEMICAL ASPECTS AND TRANSCRIPTIONAL ANALYSIS OF CANDIDATE CYPS INVOLVED IN CAFESTOL AND KAHWEOL BIOSYNTHESIS

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Brazil is the biggest coffee producer and exporter in the world, and the second largest consumer market. Studies aiming cup quality improvement and plant tolerance to biotic and abiotic stresses are important to coffee agrobusiness. Diterpenes present in the lipid fraction of coffee beans are important in plant defense mechanisms, beverage nutraceutical and sensorial properties. Two diterpenes of the kaurane family are exclusively found in coffee plants: cafestol (Caf) and kahweol (Kah). The final steps of Caf and Kah biosynthesis in coffee plants have not yet been elucidated, but in plants, most terpenoids are synthetized by members of cytochrome P450s gene family (CYPs). In order to understand genetic and biochemical aspects of diterpenes biosynthesis, we quantified Caf and Cav in flowers as well as fruit perisperm (30 to 210 days after flowering - DAF). We also performed transcriptional analysis of eight CYP genes in arabica coffee. Caf levels were detected mainly in flowers as well as in the perisperm decreasing after 120 DAF. On the other hand, Kah concentration increased with perisperm development reaching a peak at 120DAF. Using the Brazilian Coffee Genome EST database, we selected eight CYPs for transcriptional analysis by qPCR in leaves, flowers and fruit perisperm at three developmental stages (90DAF, 120DAF and 150DAF). For five genes we observed a similar pattern between diterpenes concentration and gene transcription. Three CYPs had transcriptional patterns similar to Caf accumulation whereas those of the two CYPs were related with Kah accumulation. These five CYPs warrant further investigation as potential candidates genes involved in the final stages of Caf and Kah biosynthetic pathway.

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EVALUATION OF KAHWEOL AND CAFESTOL LEVELS IN  
ETHIOPIAN COFFEA ARABICA L. ACCESSIONS GROWN IN BRAZIL

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As a consequence of their botanic characteristic and domestication process, the genetic diversity of cultivated Arabica coffee genotypes is extremely narrow. A higher phenotypic and molecular variability is observed in the Ethiopian coffee accessions making these genotypes a valuable resource for breeding. Lipids are an important component of coffee beverage flavor and aroma. Coffee oil is rich in diterpenes of the kaurane family, mainly cafestol (Caf) and kahweol (Kah), which have increasingly received attention due to their physiological effects in human health. In this context the aim of this study was to characterize the Caf and Kah levels of 13 *Coffea arabica* Ethiopian accessions, and four cultivated Arabica genotypes (Catuaí Vermelho, Mundo Novo, Typica and Bourbon), maintained in the Instituto Agronômico do Paraná (Londrina, Brazil) at the same edaphoclimatic conditions. Diterpenes extractions were carried out in green coffee based in a protocol previously developed by our group, using direct saponification with KOH (0,2g of material), extraction with terc-butyl methyl ether, and clean up with water. A reverse-phase HPLC column with isocratic elution with acetonitrile/water (55/45 v/v) was used for detection and quantification of Kah at 290 nm and Caf at 220 nm. Kah concentration was higher than Caf in eight genotypes: E017, Catuaí vermelho, Mundo Novo, Typica, E454, E037, E272 and E237. Meanwhile, the inverse was observed for 9 genotypes, where Caf levels were higher than Kah: E123b, E516, E464, E007, Bourbon, E565, E238, E123a and E270. The highest levels of Kah were observed in the Ethiopian accession E017 (1040 mg/100 g). On the other hand, the Ethiopian accession E270 showed the highest level of Caf (838 mg/100g). Further studies associating these data with genotyping data as well as gene expression profiles will be useful to identify molecular markers and/or key genes involved in the metabolism of coffee diterpenes.

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**PB 243**
**RESISTANCE TO COFFEE LEAF MINER IN PROGENIES FROM RC<sub>5</sub>  
AND RC<sub>6</sub> GENERATIONS**
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Coffee is an important agricultural product in Brazil, which is the main producer and worldwide exporter. Coffee production can be affected by several pests and diseases, and the leaf miner (*Leucoptera coffeella*) is a major pest, causing defoliation and affecting the fruit production. However, the production efficiency can be substantially improved by planting resistant cultivars. The objective of this study was to evaluate, under laboratory conditions, RC5 and RC6 progenies from under selection populations regarding resistance to leaf miner.

The progeny test was planted in March 2003 in the Experimental Center of Instituto Agronomico (IAC). The design was a block consisting of six randomized treatments and five replications, with three plants per plot, totaling 90 plants. For evaluation, plants leaves were collected in the field, taken to the laboratory and submitted to insect infestation in cages. Later, leaf-disks extracted from oviposition places on leaves were kept in plastic boxes with moistened foam. The disks evaluation was performed seven days after laying, based on the type of reaction using a rating scale already established, in which the disks were classified as: 1 = resistant with points lesions, 2 = moderately resistant with small lesions , 3 = moderately susceptible with large and irregular lesions 4 = susceptible to large and rounded lesions.

The ranking of coffee plants resistance response to leaf miner are shown in Table 1.

**Table 1.** Resistance to leaf miner of RC<sub>5</sub> and RC<sub>6</sub> progenies .

Progeny	Generations	Plants number	<i>Leucoptera coffeella</i>				
			1*	2*	3*	4*	Mean
Catuaí Vermelho IAC99	Control	14	0	0	8	6	3,43
H20050	RC <sub>6</sub>	14	1	0	8	5	3,21
H20049	RC <sub>6</sub>	15	3	1	7	4	2,80
H20034	RC <sub>6</sub>	15	5	0	3	7	2,80
H20033	RC <sub>6</sub>	15	3	0	7	5	2,93
H20032	RC <sub>5</sub>	15	4	0	5	6	2,86

\* Notes assigned to plants

The results related show that the control cultivar, the Catuaí Vermelho IAC99 and the H20050 progeny were scored above 3 points, and the H20049 progeny had the lowest level of infestation. Observing the variation of the scores assigned to plants, an intense segregation for the characteristic was detected, which should be considered in next breeding steps.

## PB 244

PERFORMANCE OF AN ARABICA CULTIVAR ONTO A DIVERSE  
*Coffea* ROOTSTOCK GERMPLASM**MEDINA FILHO, Herculano P.\*, BORDIGNON, Rita\***

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Coffee improvement program of Instituto Agronômico is primarily focused in the development of cultivars of *Coffea arabica* aiming at high yields and other attributes of plant canopy that, in turn, depend on the attributes of the root system. Many and varied scion rootstock interactions are known in vegetative propagated fruits, rubber trees and other cash crops. Little has been exploited in commercial coffee in Brazil except for grafts of *C. arabica* seedlings onto *C. canephora* cv. Apoatã to avoid nematode attacks. In the present investigation 509 control plants derived from seeds of *C. arabica* cv. Obatã were compared to 446 plants of Obatã grafted at hypocotiledony stage on 68 open pollinated progenies of *Coffea* germplasm comprising 15 related groups of accessions, mutants, hybrids or derivatives of *C. arabica*, *C. canephora*, *C. eugeniooides*, *C. racemosa*, *C. salvatrix*, *C. kapakata*, *C. dewevrei*, *C. liberica* and *C. stenophylla*. Plots were set up in 2002 in nematode free, low fertility typic Haplustox soil in Campinas and evaluated until 2012. Vigor, yields and general performance were estimated by plant measurements of height, width, trunk circumference in addition to scores assigned to yield, leafiness, vigor, wilt, ripening and cup quality in one or more occasions to study the influence of the genetic diversity of rootstocks on the canopy characteristics of Obatã. Since the first years it was observed greater variability among grafted plants as compared to controls, evidencing the influence of the rootstocks or their interactions on the Obatã scion. The magnitude of variation was not the same either among parameters or along years, but the effects of some of the germplasm groups were evident from the second or third year becoming more intense by the end of assayed period. Missing plants were also recorded. In 2003 average survival was 100% in control groups compared to 98.3% in the grafted ones. In 2006 this was 99.6% and 95.8%, in 2008, 95.1% and 91.4% but in 2012, after quite unfavorable conditions, shifted to 59.7% and 73.7% respectively, with 6 germplasm groups varying from 81.6 to 100% survival. ANOVA for 2012 height and width identified 5 significantly higher and 6 wider groups corresponding to *C. canephora* accessions, BC<sub>1</sub>, *C. eugeniooides* 4n x *C. arabica*, *C. salvatrix* hybrid derivatives and *C. dewevrei* 4n x *C. arabica*. Throughout the years BC<sub>1</sub>, *C. eugeniooides* 4n x *C. arabica* had the strongest positive influence on vigor but surprisingly, 3 accessions of *C. eugeniooides* induced the weakest canopies of all groups. Within group analysis, some specific progenies of Mokka and Maragogipe derivatives, Conilon, BC<sub>1</sub>, *C. eugeniooides* 4n x *C. arabica*, *C. arabica* x *C. dewevrei* 4n and *C. racemosa* x *C. arabica* BC<sub>2</sub> derivative induced the most vigorous canopies. Yields correlated well with vigor and were quite influenced. Cup quality and ripening did not show any consistent difference among Obatã controls and the ones grafted onto different groups. Within groups, variation reflects genetic variability among rootstock plants of same progeny, as expected on the basis of their open pollination, outcrossed reproduction. Thus, selection of favorable rootstock genotypes would be most efficiently done on the basis of individual plants. One could consider rescuing selected ones after cutting back their canopies but this would be certainly hindered by the absence of buds in the hypocotyl. A strategy to circumvent this drawback is to clone the tops of rootstock seedlings on occasion of the grafting procedure, successfully done and easily performed provided hypocotyledons rooted promptly. Individual selections thus secured form the base population for an arabica rootstock breeding program.

## PB 245

## PHYLOGENETIC ANALYSIS OF HEMILEIA VASTATRIX AND RELATED TAXA USING A GENOME-SCALE APPROACH

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Abstract: For more than a century, Coffee Leaf Rust caused by the biotrophic fungus *Hemileia vastatrix*, has increasingly stood out as one of the major factors hampering Arabica coffee production. Since its first historical outburst in the 19<sup>th</sup> century in Sri Lanka, this disease has rapidly spread worldwide and currently occurs in nearly all the regions of the world where coffee is grown. Despite its widespread distribution and negative economic impact, little is known about its evolutionary origin and phylogenetic placement in the fungal tree of life. Attaining this knowledge, however, would provide fundamental insights on the evolutionary context in which *H. vastatrix* emerged, which in turn could have important implications to understand the evolution of pathogenicity in this pathogen and in other rusts as well. With this in mind, we are undertaking a genome-scale approach that will allow *H. vastatrix* and other rust fungi to be placed in the fungal tree of life with unprecedented detail by using complete proteomes of five Pucciniomycotina species, approximately 250 000 publicly available EST sequences from several Pucciniomycotina species and *H. vastatrix*'s recently obtained transcriptome. A high quality matrix that includes orthologs, co-orthologs and recent paralogs is currently being prepared with a sophisticated orthology detection strategy. On a first approach, we have been able to identify at least 1040 single-copy orthologs that will be used for the phylogenetic analyses. Providing robust and resolved phylogenetic relationships will lay the ground for the identification of genes or gene families that are exclusive to *H. vastatrix* as well as genes of rapid evolution and/or subject of positive selection, which would be prime targets for functional studies aiming at disease control and prevention. This information will ultimately contribute significantly to advance our knowledge on *H. vastatrix*'s pathogenicity.

This work is supported by projects PTDC/AGR-GPL/119943/2010 and PTDC/AGR-GPL/114949/2009, from Fundação para a Ciência e Tecnologia (Portugal), by grant UI88/5537/2011 (Universidade de Aveiro, Portugal) and by CEA/Genoscope-INRA-IRD Collaborative project (<http://www.genoscope.cns.fr/spip/Identification-of-virulence.html>) (France), whose funding is gratefully acknowledged.

**PB 246****THE KARYOTYPE OF HEMILEIA VASTATRIX,  
THE CAUSAL AGENT OF COFFEE LEAF RUST**

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*Hemileia vastatrix* Berkeley and Broome causes the most important disease of Arabica coffee, coffee leaf rust. Although various aspects of *H. vastatrix* biology have been unveiled at the cytological, genetic and transcriptomic levels, little is known on its chromosome composition. In other fungal plant pathogens, the analysis of the karyotype revealed the association of pathogenicity factors to supernumerary chromosomes. Therefore, in this work the karyotype of *H. vastatrix* was investigated with the purpose of better understanding the fungus biology, namely by the identification of polymorphisms in the chromosome content of two distinct physiological races. Two complementary techniques were elected to unravel *H. vastatrix* chromosome number: a cytological one based on the application of the germ tube burst method (GTBM) to isolate metaphase nuclei in germinating uredospores, followed by DAPI staining of DNA; and an electrophoretic one based on the pulse field gel electrophoresis (PFGE) of germinating uredospore samples. In addition, the rDNA loci in *H. vastatrix* interphase nuclei were visualized by fluorescence in situ hybridization (FISH). The observation of the nucleolus was possible using fungal ribosomal probes. The implementation of these techniques led to the estimation of seven to 13 chromosomes for *H. vastatrix*, enabling the study of its karyotype, which may contribute to link virulence spectra to the putative polymorphisms detected, and also to localize genes connected with pathogenicity.

This work was financially supported by Fundação para a Ciência e a Tecnologia (Portugal) project PTDC/AGR-GPL/114949/2009 and grants SFRH/BPD/65965/2009 (attributed to Sílvia Tavares) and SFRH/BD/16684/2004 (attributed to Andreia Loureiro).

## PB 247

INTEGRATED CYTOLOGIC AND PROTEOMIC ANALYSIS OF *COFFEA ARABICA* - *HEMILEIA VASTATRIX* INTERACTIONS

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Coffee leaf rust, caused by the fungus *Hemileia vastatrix* Berk & Br., is the most widespread disease of *Coffea arabica* L. cultivars. Coffee – rust interactions are governed by the gene-for-gene relationship, being the resistance conditioned at least by nine major dominant genes (SH1-SH9) singly or associated. A cellular and proteomic approach was used to study *C. arabica* – *H. vastatrix* compatible and incompatible interactions. In the incompatible interactions the first cytological changes corresponded to hypersensitive host cell death (HR), observed in more than 50% of infection sites, at 48h after inoculation. High-resolution two-dimensional fluorescence differential gel electrophoresis (Refraction-2D™), allowed the separation of 30 µg of protein per sample in a 13cm gel strips with immobilized pH 4-7 linear gradient. Differentially expressed spots were found from 4.8 to 5.6 of pI values, presenting a MW from 45 to 60 kDa. The identification of those proteins by matrix assisted laser desorption/ionization time of flight-mass spectrometry (MALDI – TOF/TOF MS) followed by homology in several NCBI databases will provide insights in the molecular function of proteins specific for each of the interactions. With this methodology we expect to find proteins that are potential candidate resistance markers.

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## PB 248

PHENOTYPING AND GENOTYPING GENETIC RESOURCES  
OF *COFFEA ARABICA* at IAPAR. FAO COLLECTION,  
PRELIMINARY RESULTS .

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Plant Breeding of *Coffea arabica* has been based since the 1950s mainly on interspecific cross followed by backcrossing to *C. arabica* and selfings. The genetic diversity of *C. arabica* in Ethiopia, its region of origin, was explored at the same time. Its use for *C. arabica* breeding, though limited to a few F1 crosses with cultivars, proved to be efficient in terms of genetic gain regarding important coffee agronomic characteristics such as vigor, adaptability and quality.

A collection derived from the 1964-65 FAO survey in Ethiopia was established at IAPAR in Londrina, Paraná, Brazil in 1976. Multidisciplinary studies aiming at describing the phenotypic diversity of that collection have

been conducted. At this stage the main focuses are drought tolerance and quality, with the goal of providing selection tools for plant breeders.

Self pollinated progenies of 179 plants representing 115 Ethiopian accessions were established on IAPAR-Londrina research station, from 2009 to 2012. 47 of them were also established at CPAC near Brasilia, DF. In both locations the progenies were submitted after one year to two treatments: irrigated vs. not irrigated. In addition 113 progenies at nursery stage were submitted to dry spells in a glasshouse. Various growth parameters were measured, as well as plant response. The common control cultivars were IAPAR59 and Catuaí vermelho.

Genotyping was undertaken using SSR markers that were polymorphic within these accessions. The analyses confer with phenotypic data regarding within accession homogeneity; Preliminary results regarding the relation between genetic and phenotypic diversity are presented.

**PB 249****IDENTIFICATION AND ANALYSIS OF POLYMORPHISMS IN THE PROMOTER REGION OF THE GENE *DREB1A* FROM CONTRASTING HAPLOTYPES OF *COFFEA CANEPHORA***

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Although some physiological studies have resulted in a better understanding of the mechanisms involved in drought tolerance in coffee, information is missing about the molecular mechanisms controlling the response of coffee to drought. In this regard, recent studies performed in our laboratory identified several candidate genes showing differential expression in leaves of contrasting clones of *Coffea canephora* var conilon for this trait. Among these results, the gene *DREB1A* showed differential expression in the leaves of the clones 14 (drought tolerant) and 22 (drought susceptible) subjected or not to water stress. The aim of the present study was to identify and analyze the polymorphisms within the promoter region of the gene *DREB1A* in these two clones of *C. canephora*, but also in other accessions of *Coffea* genus (*C. eugeniooides* and *C. arabica*). This allowed the identification of *cis*-regulatory elements of the gene *DREB1A* and also of polymorphisms in the promoter region of this gene. For example, the presence of *cis*-regulatory elements from transcription factors belonging to ABA-dependent pathway suggested the possibility of cross-talk between the two networks (ABA-independent and -dependent) response in the regulation process of the *DREB1A* gene. The polymorphisms permitted the identification of different haplotypes among those genotypes and the allelic distribution of these loci correlated with the *C. canephora* and *C. eugeniooides* alleles in the *C. arabica* genotype. These polymorphisms may indicate the involvement of different haplotypes in the genetic control of drought tolerance. In order to elucidate the involvement of *cis*-elements and the role of the polymorphism found in the functionality of this promoter upon the coffee response to drought, transformation constructs were engineered using the binary vector pBI121 combined with different segments of the gene promoter *DREB1A*, isolated from the clones 14 and 22 of *C. canephora* and are currently being tested in transgenic citrus. These results will be presented and discussed.

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## PB 250

## NO-HITOMICS: UNDERSTANDING THE COFFEE UNKNOWNS.

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Due to the recent advances in sequencing technologies, coffee genomics is progressing fast and sequence data is readily becoming available. However, many coffee genes do not display sequence similarities with public databases and are therefore, called "no-hits". Data produced by the Brazilian large-scale EST project of coffee resulted in around 10 thousand no-hit genes. This indicates that about one-third of all data produced regards no-hit genes which function remains largely unknown. In order to have a first clue on the biological function these genes might have, we have performed transcriptome analysis of no-hit genes by screening cDNA-microarrays with cDNA probes obtained from different coffee tissues (leaves, flowers, fruits, meristems and roots) and conditions (tissues from coffee plants submitted or not to abiotic and biotic stresses). Special attention was paid to the no-hit genes and further validation by qPCR was performed for some of them. Furthermore, we have also checked if tryptic peptides corresponding to these no-hit genes were also identified in experiments of protein profiling followed by mass spectrometry (MS) previously performed in our lab, in order to confirm if these genes were also translated into proteins. Functional analysis of some of the identified no-hits using model plants followed by phenotype characterization will be performed to ascertain their biological function.

This work was supported by the CBP&D/Café, FINEP and INCT-Café (FAPEMIG/CNPq).

## PB 251

## ROOTOMICS: THE FIRST HIGH-THROUGHPUT SEQUENCING OF cDNA EXTRACTED FROM ROOTS OF DIFFERENT CLONES OF COFFEA CANEPHORA VAR. CONILON SUBMITTED TO DROUGHT

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In many coffee producing countries, water availability constitutes the major environmental constraint affecting crop production. In the *Coffea canephora* var. Conilon, several clones tolerant and susceptible to drought were selected and studied at the physiological level. Even if the clonal tolerance to drought in robusta coffee still remain largely unknown, it was shown that rooting depth was greater in drought-tolerant than in drought-sensitive clones. Obviously, roots are of great importance in the response of plants to drought since they are responsible of water uptake by deep and dense root systems. In the frame of our researches looking for candidate genes implicated in genetic determinism of drought tolerance in coffee, roots from three drought tolerant clones (named 14, 73 and 120) and clone 14 (drought susceptible) of *C. canephora* var. Conilon submitted (NI: non-irrigated) or not (I: irrigated) to drought were used to generate cDNAs that were sequenced using the 454 strategy (Roche). Such a transcriptomic work is of a great importance because it should allow the identification of new genes specifically expressed in roots that are largely underrepresented in coffee EST sequencing projects already realized worldwide. This is for example the case of the Brazilian Coffee Genome

Project that, even considered as the greatest initiative in generating coffee ESTs (187,412 ESTs from 43 cDNA libraries), only produced 3,440 ESTs (1.8% of the project) from a limited number (3) of root cDNA libraries. The sequencing results will be presented as well as the preliminary data of electronic northern performed in order to identify new genes differentially expressed in the roots drought-tolerant and -susceptible clones of *C. canephora* under the different conditions (I vs. NI) of irrigation.

This work was supported by CBP&D/Café, FINEP and INCT-Café (FAPEMIG/CNPq).

**PB 252**

**DEFENSE GENE EXPRESSION INDUCED BY A PLANT EXTRACT FORMULATION AND PHOSPHITES IN COFFEE SEEDLINGS AGAINST *Hemileia vastatrix***

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Coffee leaf rust, caused by *Hemileia vastatrix*, is one of the most destructive diseases of coffee worldwide. Our research group is conducting studies aiming at controlling this disease by activating defense mechanisms inherent to the coffee plant. Analysis of defense-related gene expression and activity of defense enzymes, in response to treatment with elicitors are important tools for studying the mechanisms of induced resistance. In this work we sprayed coffee seedlings with NEFID (coffee-leaf extract formulation), manganese phosphite and the association NEFID + copper phosphite + manganese phosphite and characterized levels of quantitative expression of two defense genes, *CAT* and *PAL*, which encode catalase and phenylalanine ammonia lyase, respectively. Activities of these enzymes were also evaluated, in a time course before and after inoculation with *H. vastatrix*. *CAT* and *PAL* genes were induced in coffee seedlings by all treatments, exhibiting widely varied expression profiles according to the elicitor sprayed and the period analyzed. Before inoculation with *H. vastatrix*, the highest levels of expression of *CAT* and *PAL* genes were found in plants sprayed with NEFID. After inoculation we observed variations between the expression of these genes, the analyzed elicitors and times, but the highest levels of expression for both genes were found in plants treated with manganese phosphite or NEFID + copper phosphite + manganese phosphite. In general, *PAL* activity showed a different profile in relation to *CAT* activity, so that there was less activity of the enzyme *PAL* for most of the time course analyzed.

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**PB 253**

**ARABICA GENETIC MAPPING USING SSR MARKERS IN RELATIONSHIP WITH HIGH DENSITY ROBUSTA MAP.**

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Two main coffee species are cultivated worldwide ranking among the most valuable agricultural exports from tropical countries. *Coffea arabica* ( $2n=4x=44$ ) is an allotetraploid containing two genomes originated from the diploid wild coffee species, *Coffea canephora* and *Coffea eugenoides*. Arabica cultivars are characterized by a low genetic diversity due to limited accession diffusion in producing countries even if a larger genetic diversity was found in Ethiopia the center of origin of this coffee species. In contrast, *C. canephora* is a diploid allogamous species ( $2n=2x=22$ ) with considerable variability.

Recent genomic and genetic data were at the origin of a high density Robusta map that has been used to initiate the Arabica mapping using the same set of SSR markers. These highly polymorphic markers can be easily used to map and characterize independently the two diploids genomes included in Arabica. A large number of these SSR markers has been obtained through 454 DNA Arabica sequencing. A total of 22500 microsatellites was detected including di to hexa-nucleotide patterns with a minimum of five tandem repeats. The di-nucleotide pattern SSRs were more frequent than others especially  $GA_n$  (36%),  $AT_n$  (32%),  $GT_n$  (14%) and  $GC_n$  (1%).

A F2 segregating population (138 individuals) was obtained from a cross between two Ethiopian Arabica Ar8 and Ar36B. The genetic map obtained so far include more than 350 loci distributed over 66 linkage groups. Its length is 2600 cM which represents approximately 65% of the final estimated size of Arabica map. Up to now, the Robusta and Arabica genetic maps show co-linear organization of the shared loci. But the two genetic maps obtained have already displayed significant differences, in the majority of cases, the genetic distances between loci are more important in Arabica than in Robusta.

The partial Arabica genetic map has allowed the detection of several QTLs associated with agronomical, biochemical and technologic traits of interest for the breeders.

**PB 254****QTL DETECTION ON ROBUSTA USING SINGLE AND MULTI-PARENT MAPPING POPULATIONS IN DIFFERENT LOCATIONS.**

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A quantitative trait locus (QTL) analysis design for single and multi-parent populations were carried in coffee (*Coffea canephora*) which is a diploid allogamous perennial species with a high heterozygosity rate.

This study was performed on two progenies (FRT58 X FRT51) and (FRT67 X FRT51) planted in two locations (Ecuador and Thailand), each of these two segregating populations having approximately 200 progenies. Two parents belong to the Congolese group (FRT 51 and FRT 67) since FRT58 belongs to the Guinean group. These three parental genotypes were selected in a Robusta collection based on their genetic background and their phenotypic characteristics, especially their agronomic and sensory performances. Genetic maps of these populations were established using SSR markers allowing the detection of numerous QTLs related to agronomic, biochemical, technological and also sensory characteristics. This quantitative analysis showed that the favorable alleles are mainly carried out by the parents FRT 58 and FRT67. The study also demonstrates that a core set of QTLs is detected independently of the two locations under study.

In Ecuador, a connected factorial mating experiment including seven parents was also genotyped using a set of 84 SSRs to produce a consensus genetic map used for QTL detection. A total of 11 progenies of 32 individuals each were phenotyped individually using field data and biochemical bean composition predicted by NIR. The MCQTL software allows the QTL mapping in multi-cross design with additive and dominance models. For the 24 quantitative traits studied, most of the QTLs have been identified using the additive model and few QTLs with dominance effects were detected. This multi-population analysis reveals several regions of major QTL affecting biochemical bean composition with potential influence on the cup quality.

The comparison of the QTL detection between single and multiple progenies designs reveals that the across-family analysis is efficient due to the interconnected families. Favorable alleles were detected in all parents involved in the multi-family populations. This approach involving several parents is promising for an application on polycross progenies, traditionally used in breeding programs.

Some major QTLs were also detected in the two mapping cross designs (single or connected progenies) showing the complementary of these two approaches.

**PB 255****EARLY SELECTION FOR DROUGHT RESISTANCE IN COFFEE**

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Global warming with increased temperature and limited rainfall will generate more drought incidences in this century. In the future, it will strongly affect coffee production as coffee trees have significant water requirements for their growth and development. The environmental changes will limit suitable areas for coffee production. Our breeding activity aims to select Arabica plants at early stage for their drought resistance and investigate on their physiology parameters related to stress. Seeds were collected on a progeny derived from wild accessions and plantlets were screened under water-stressed conditions in the greenhouse using an hydroponic system. Water stress was induced by adding polyethylene glycol to the nutrient solution; PEG is a polymer that has long been used in research to mimic water-stressed conditions. Results are showing that a combination of high values for three parameters (stomatal conductance ( $G_s$ ), leaf greenness (SPAD value), maximum quantum yield of PSII primary photochemistry ( $F_v/F_m$ )) is highly correlated with the capacity of plantlets to cope with drought. A number of plants has been selected based on drought tolerant score and other physiological parameters. Further investigation for their drought tolerance will take place in the field in order to confirm results obtained in the greenhouse. Output from physiological measurements will be used to identify genetic loci related to these traits. DNA markers related to drought tolerance will be used in breeding program to accelerate the process of selection.

**PB 256****DNA TRACEABILITY FOR VARIETY PURITY IN NESPRESSO PRODUCT**

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The coffee market is regularly developing finished products based on a single variety. Some of them are well recognized by the consumer for example Maragogype, Moka, Blue Mountain or Bourbon. The development of this product category affords some similarities with the wine market which is organized by grape varieties in many countries and could bring opportunities for premium product differentiation. Nevertheless, the green coffee market is not organized by varieties but mainly by species (Robusta versus Arabica) and by producing countries. The distinction of coffee varieties at the green coffee stage is almost impossible using physical or chemical analytical tools. A DNA method was developed to allow the identification of varieties through the value chain, from the field to the finished product. The method is applied on routine basis to guarantee the purity and authenticity of raw material used by Nespresso.

The traceability analysis is built on a large database of microsatellite markers (SSRs) that discriminate Arabica cultivars which are usually characterized by a low genetic diversity. Targeted varieties are identified by a unique set of microsatellites. These selected SSRs will be used for the assessment of the desired variety and the rejection of batches when non expected alleles are detected in the sample. The tool can be used to check raw material entering the factory but also to identify the coffee farms producing the desirable varieties. The traceability technology was improved through close collaboration with suppliers.

The quality control test was recently applied and fine tuned using green bean batches from farms in Southern Brazil, which grow red and yellow bourbon varieties. This Arabica blend is at the origin for the sensory specificity of Dulsão do Brasil capsule. Genetic diversity studies were performed among these farms using a set of eight microsatellite markers (SSRs) selected for their ability to discriminate the Bourbon origins. The DNA tool helped guide the farm selection. The same procedure could be applied to other Arabica varieties according to requirements and claims of the final coffee product.

The method is being improved to increase the capacity of sample analysis and decrease its cost. In addition, a new technology is under test based on high throughput 454 DNA sequencing. This assay will provide higher reliability and accuracy both for genetic diversity studies and quality control tests.

**PB 257**

### MASS PROPAGATION OF COFFEE PLANTLETS TO INCREASE THE SUSTAINABILITY OF ROBUSTA COFFEE PRODUCTION WITHIN THE NESCAFE PLAN

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Robusta coffee production is leveling off or declining in several producing countries in the face of technical and economic challenges: declining farm productivity, economic pressure on coffee farming, strong market price fluctuations and competing crops with higher profitability. Farm productivity is strongly dependent on the use of appropriate farm practices and also on the production potential of coffee trees. The ageing of coffee orchards, together with poor genetics strongly limit this potential.

The Nescafé Plan was launched by Nestlé in 2010, with the aim of increasing the sustainability of coffee from farm to cup. A major focus of the Plan is on sustainable coffee farming and the improvement of farmer income. To this end, coffee plantlets with improved genetics are made available to growers and technical assistance is provided to improve yields and coffee quality.

In addition, buying stations close to production areas give the farmers the option to benefit from a shortened value chain and a transparent buying system that rewards quality.

The propagation of coffee clones on a large scale is a challenge that is met with complementary approaches. On the one hand Nestlé implements an accelerated propagation method that is based on in vitro technologies using somatic embryogenesis. The plantlets produced are either destined to farmers or to the establishment of clonal gardens. This method has been optimized to limit in vitro steps; today, a single operator can produce up to 1.5 million embryos in a year. The average embryo to plantlet conversion rate varies country to country and can reach 80% in the best cases. Under these conditions, the method allows the production of millions of embryos from limited material within 2 years at a cost that is competitive with conventional techniques.

The production of rooted cuttings comes in complement to somatic embryogenesis where the availability of space and labour makes it practical.

Mass propagation of coffee trees within the Nescafé Plan is now implemented in three countries: Thailand, the Philippines and Mexico. In the latter country, Nestlé has partnered with Agromod, a company specialist of plant production in vitro. The transfer of our accelerated propagation technology allows the production of embryos and plantlets in situ, shortening the distance between the laboratory and the farmer.

## PB 259

MOLECULAR CHARACTERIZATION OF NOVEL GENES SIMILAR TO  
*Cry 36 Aa1* OPTIMIZED FOR PEST RESISTANT TRANSGENIC COFFEE**SUREKHA, Kuyyalil \*, NAIDU, Rayankula \*\*, ROYER, Monique\*\*\***

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Indian coffee is struggling from the attack of *Xylotrechus quadripes* white stem borer and *Hypothenemus hampei* Coffee berry borer which are endocarpic coleopterans difficult to control by conventional means. The transgenic approach may represent an efficient compliment to traditional pest control strategies, as the insecticidal toxin produced by the plant would be present within the tissue on which the pest feeds. Bioassay procedures based on artificial diet were developed and standardized for *H.hampei* and *X.quadripes* for estimating the insecticidal activity of *Bacillus thuringiensis* which is the most important source of genes for the development of pest-resistant transgenic plants. *B.thuringiensis* isolates potentially active against coleopterans prepared by CIRAD were tested for toxicity against both targeted pests through in vivo bioassays and twenty four were found putatively active and molecular analysis confirmed the presence of *cry1I* and *cry7/8* genes responsible for insecticidal activity. Of this three isolates viz. (3A021,T01001,T33001) which had shown maximum mortality rate 65-76% were subjected to all molecular biology tools including purification and transfer on PVDF membrane, southern blot, western blot, DNA sequencing and N terminal protein sequencing .Crystal proteins purified from 3A021 showed that first 10 amino acids were similar to *cry 1A* gene. But the presence of *cry1A* toxin cannot explain the insecticidal activity against CBB and WSB. Analysis of T01001 revealed three crystal proteins at 150,130 and 29kDa respectively and first 18 amino acids of these two proteins were 100% similar to first amino acids of *Cry 1B* and *Cry1A* crystal protein respectively and third one has similarity to *Cyt 1A* but *Cyt 1A* cannot be expressed in plants because of its cytolytic effect. T33001 revealed 65 and 62kDa proteins have 80% and 70%similarity to first 10 amino acids of *Cry36Aa1* . Based on the amino acid sequence of two putative conserved domains two degenerated primers were designed viz. the primer *cry 35* and primer *binA* specific for the conserved sequence respectively. Primers *33Hbis* and *cry35* amplified a 1kb DNA fragment which was cloned and sequenced and revealed that the amino acid sequence coded by this PCR product has 61.3% dissimilarity with *Cry36Aa1*, justified that these are new genes.T33001 produces two crystal proteins similar to the *Cry36Aa1* toxin which was patented by Monsanto as a *B.thuringiensis* crystal protein active against a coleopteran (*Dabrotica virgifera*, Patent WO 00/66742,2000).So we propose genes from T33001 could be used to transform to coffee. This is the outcome of collaborative project involving Coffee Board, India and CIRAD, France, in the frame of Indo French Centre for Promotion in Advanced Research (IFCPAR).

**PB 260**

**TRANSPOSABLE ELEMENTS AS NEW POWERFUL TOOLS FOR STUDYING COFFEE GENETIC DIVERSITY AND PHYLOGENY.**

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Transposable elements are ubiquitous mobile DNA sequences found in all eukaryotic and prokaryotic genomes. They are divided in two classes according to their mechanism of transposition. Class I elements move according to a “copy and paste” model. They are called retrotransposons as the mechanism involves a RNA as intermediate and a reverse transcriptase. There are three main types of retrotransposons among which, one has long terminal repeats (LTR). Class II elements’ transposition is catalyzed by a transposase, which moves the element from one locus to another according to a “cut and paste” model. Class II elements are referred as DNA transposons. In some cases, Helitrons, DNA transposons can undergo a replicative transposition.

Transposable elements activity is responsible for generating considerable natural polymorphism that can be used to study within and between species diversity and to identify possible population genetic structure and phylogenetic relationships.

We recently isolated different types of transposable elements from the *Coffea* genome that we used to assess genetic diversity, phylogenetic relationships and intraspecies differentiation in *Coffea* [1]. Two TY1-Copia LTR retrotransposons (called Nana and Divo) allowed us to resolve different species lineages in the *Coffea* genus according to time and rate of transposition of each element. Through several experimental approaches (REMAP, SSAP, RBIP) we showed that the retrotransposon-based markers were useful in highlighting *Coffea* genetic diversity and the chronological pattern of speciation/differentiation events. A Miniature Inverted-repeat Transposable Element (MITE), called *A/lex-1*, was found to be inserted in an intron of a transcribed gene [2]. The insertion pattern of the *A/lex-1* MITE at this specific locus in *Coffea* species indicates an original path of species differentiation including gene flows between ancestral forms that happened before the present. LTR retrotransposons and MITEs appear to be powerful tools to analyze speciation events and to trace phylogenetic relationships among species. These elements will be very useful to solve the unresolved branches still present in the latest studies on *Coffea* phylogenetic studies [3].

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**PB 261**

**IDENTIFICATION OF ACTIVE LTR-RETROTRANSPOSONS IN THE COFFEA CANEPHORA GENOME THROUGH BAC END SEQUENCE ANALYSIS**

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Transposable elements (TE) are mobile DNA fragments that are present in all Eukaryotic and prokaryotic organisms. They share several key properties such as the ability to move from one chromosomal location to another, to create phenotypic mutations and to amplify their copy number within the host genome. They are classified according to their mode of replication: Class I elements, or retrotransposons, move through a RNA intermediate, whereas Class II elements or transposons move directly through a DNA molecule. LTR retrotransposons (LTR-RTN) are the most redundant TE in plant genome and can make up to 80% of nuclear genomes. They are considered as one of the main evolutionary forces in angiosperms. Two genomic Bacterial Artificial Chromosome (BAC) libraries (*Bst* YI and *Hind* III) have been recently constructed in *Coffea canephora*. A total of 72,000 clones were generated and 136,027 extremities (called BAC-ends) were sequenced (mean sequence size 680 bp), representing 7.5% of the estimated genome size. Here we present the first large-scale identification of LTR-RTN in *C. canephora* based on the *in silico* analysis of BAC-end sequences. Potential transposable elements were identified in 20.7% and 12% of *Bst* YI and *Hind* III BAC-ends libraries by similarity with plant TE proteins. A vast majority of them (93%) belong to the Class I LTR-RTNs. These results suggest that LTR-RTNs make up a significant part of the *C. canephora* genome and that they could be assembled into a large sequence with the appropriated algorithm. To test this hypothesis, we use the Assisted Automated Assembler of Repeat Families algorithm [1] to assemble the 136,027 BES into 1549 contigs of repeated sequences. Among them, 24 contigs ranged from 13,433 to 4,257 bp showing strong similarities to LTR-RTNs, and 8 of them were annotated as complete elements. Strong similarities with *C. canephora* available EST sequences were found for Twenty-one LTR-RTNs, suggesting that they are potentially expressed and then may represent active elements. Leaves and fruits cDNA libraries from *C. canephora* [2] were used as template for PCR amplifications for sixteen LTR-RTNs. We found that 8 of them are potentially transcriptionally active in *C. canephora*. In summary, we demonstrate the potential use of BAC end sequences to identify and characterize full-length LTR-RTNs in a plant genome. In *C. canephora*, LTR-RTNs appear redundant and some are transcriptionally active suggesting that they contribute significantly to the genome structure and evolution.

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**PB 262**

**LIPID TRANSFER PROTEINS IN COFFEE: ISOLATION OF A *COFFEA* ORTHOLOGS, *COFFEA ARABICA* HOMELOGS, EXPRESSION DURING COFFEE FRUIT DEVELOPMENT AND PROMOTER ANALYSIS IN TRANSGENIC TOBACCO PLANTS.**

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The non-specific lipid transfer proteins (nsLTPs) are basic proteins characterized by conserved cysteine residues, low molecular mass and high content of  $\alpha$ -helices that were originally defined by its ability to transfer phospholipids in membrane biogenesis *in vitro*. Several studies indicate that nsLTPs are responsible for plant protection against biotic stresses caused by fungi, bacteria and viruses. These proteins are widely distributed in plant kingdom and probably emerged very early during land plant evolution which may explain the enormous diversity of their corresponding genes. The *nsLTP*-multigene family confers differential expression patterns according to tissue, developmental stage and physiological condition. The expression of these genes is also responsive to abiotic stresses such as drought, low temperature, salt treatment, wounds and heavy metals exposure. Considering the importance of nsLTPs in plant metabolism, our study aims at (i) identifying different coffee *nsLTPs* gene homeologs corresponding to the *Coffea arabica* (*Ca*) ancestor sub-genomes: *C. canephora* (*Cc*) and *C. eugenioides* (*Ce*); (ii) evaluating the expression of these alleles during the bean development; (iii) studying the effects of drought on *nsLTP* expression in *C. canephora* and *C. arabica* and (iv) characterizing a grain-specific *nsLTP* promoter. Using the data of Brazilian EST Genome project, the *CaLTP1* (*C. arabica Lipid Transfer Protein 1*) gene was identified as highly expressed in coffee fruits. This was confirmed by RT-qPCR and Northern blot assays which highlighted the preferential expression in *C. arabica* fruit endosperm at 120 and 180 days after flowering (DAF). The corresponding *CaLTP1* gene promoter region (1.2 kb) was also isolated. Deletions in the 5' end of this sequence were made and tested by their ability to control the expression of the *uidA* reporter gene in transgenic *Nicotiana tabacum* plants. The histochemical assay of GUS activity showed that 1.2 kb, 1.0 kb and 0.8 kb fragments of the *nsLTP* promoter directed the *uidA* expression to all tested plant organs with different activity levels while low or null expression was detected in roots. On the other hand, the 0.4kb fragment led to the expression of the *uidA* gene only in seeds, fruit and floral buds. The expression of *LTP1*-specific alleles harbored in *Cc* and *Ce* sub-genomes of *Ca* was also identified using several combinations of specific primers. Analyses of *LTP1*-encoding cDNA and gene sequences allowed the identification of homeologous and orthologous sequences.

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IMPACT OF LONG-TERM INCREASED AMBIENT CO<sub>2</sub> ON COFFEA ARABICA AND C. CANEOPHORA PHOTOSYNTHETIC FUNCTIONING

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Coffee business involves around 100.000 million USD and employs (directly or indirectly) ca. 500 million people worldwide, based in the trading of *C. arabica* and *C. canephora* beans. In the field plants are often exposed to various environmental stresses that limit plant growth and photosynthesis, and impose changes at cell and whole plant metabolism, namely, of carbon and nitrogen. That is likely to become exacerbated in many regions as a consequence of climate changes. To a certain extent, plants are able to cope with environmental limitations and to maintain an efficient functioning due to a wide range of complementary mechanisms that protect the cell as a whole and the photosynthetic apparatus in particular. In the context of climate changes, this work aim at providing insights concerning the impact of predicted increases of atmospheric CO<sub>2</sub> on the coffee plant. For that, 1.5 year plants of *C. arabica* cv. Icatu, *C. arabica* cv. Catucaí 108 and *C. canephora* cv. Conilon (Clone 153) were transferred into walk-in chambers (EHHF 10000, Aralab, Portugal) and grown under environmental controlled conditions of temperature (25/20 °C, day/night), RH (75%), irradiance (ca. 700 mmol m<sup>-2</sup> s<sup>-1</sup>) and photoperiod (11.5 h), exposed to two defined CO<sub>2</sub> concentrations CO<sub>2</sub> (380 or 700 mL L<sup>-1</sup>). After 8 months several parameters (from morphological up to gene expression) were evaluated in the leaves developed entirely under these conditions. The first results pointed to growth (height and leaf area) increases under high CO<sub>2</sub> conditions. Although membrane permeability did not suffer appreciable modifications with elevated CO<sub>2</sub>, changes occurred in the photosynthetic apparatus functioning. The net photosynthetic rate remained higher at 700 than at 380 mL L<sup>-1</sup>, both in the morning and afternoon periods, with similar (Clone 153, Icatu) or higher (IPR108) stomatal conductance (thus, with implications on water use efficiency). Furthermore, the plants grown at 700 mL L<sup>-1</sup> showed higher photosynthetic capacity (measured at 25 °C and saturating light and CO<sub>2</sub>) and saturated at higher irradiance. That could be related to the somewhat increased electron transport rates at photosystems I and II level (when expressed in a chlorophyll basis), although a fluorescence analysis did not depicted obvious differences amongst CO<sub>2</sub> treatments in the three genotypes. These studies are under course and the results will be discussed considering a wide physiological, biochemical and molecular analysis, allowing an integrated view of the photosynthetic apparatus functioning in response to new environmental CO<sub>2</sub> availability.

**PB 264**

**AN INHIBITOR FROM *Lupinus bogotensis* SEEDS EFFECTIVE AGAINST ASPARTIC PROTEASES FROM *Hypothenemus hampei***

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The coffee berry borer, *Hypothenemus hampei* (Ferrari), is one of the most devastating coffee pests (*Coffea arabica*). Digestion in the midgut of *H. hampei* is facilitated by aspartic proteases. Seeds extracts of various plants were evaluated to identify aspartic protease inhibitors. The greatest inhibitory activity of aspartic proteases was found in *L. bogotensis* extract with a specific activity of 74.1 IU/mg, compared with extracts of *H. suaveolens*, *B. humidicola*, and *A. hypochondriacus* that showed a lower inhibition of aspartic proteases. The proteolytic activity of *H. hampei* was inhibited by 90% with 100 mg of crude extract of *L. bogotensis*, whereas it took 1 mg of crude extract of *H. suaveolens* and *B. humidicola* to inhibit the activity at 70 and 60% respectively. This is the first report of purification and characterization of seven aspartic proteases inhibitors from *Lupinus bogotensis* (LbAPI), using a combination of chromatographic methods, which were monitored by measuring the inhibitory activity of the fractions against the aspartic proteases of *H. hampei*. The amino-terminal sequence of LbAPI1, LbAPI2, LbAPI3, LbAPI4, and LbAPI5 showed identity with vicilins and b-conglutins of *Lupinus albus*, suggesting that these proteins could be coded by a family of genes. LbAPI6 and LbAPI7 consist of a polypeptide chain with a molecular mass of 12,86 and 16,91 kDa, respectively; and its amino-terminal sequence has identity with the d-conglutin of *L. albus*. LbAPI4 exhibited a molecular mass of 12,84 kDa and a single polypeptide chain. LbAPI4 was stable at 70 °C and pH range, 2-11 at 30 °C. In *vitro* assays, LbAPI4 was highly effective against aspartic proteases from *H. hampei* guts with a IC<sub>50</sub> of 2,9 mg. LbAPI4 inhibits pepsin at a stoichiometric ratio of 1:1 and a K<sub>i</sub> of 3,1 mM. Its amino-terminal sequence had 76% identity with vicilin and β-conglutin. The gene that codes LbAPI4 inhibitor corresponds to a sole open reading frame of 354 nucleotides that code for a polypeptide of 117 amino acids and have no introns. Amino-terminal sequence of LbAPI was used to amplify the entire open reading frame of the gene from total seed DNA and the complete coding sequence of LbAPI4 was cloned in pET-15b expression vector of *Escherichia coli*. The recombinant LbAPI4 produced 98% mortality to *H. hampei* when incorporated into an artificial diet at a level of 1.5%. The mortality of larvae fed with 1% LbAPI4 was 51%. This suggests that LbAPI4 may be a promising tool to make genetically modified coffee with resistance to *H. hampei*.

## PB 265

## ANALYSIS OF THE EXPRESSION PATTERN OF miRNAs, BY STEM-LOOP RT-PCR, IN COFFEE SPECIES WITH DIFFERENT PLOIDY LEVELS.

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Polypliody is a remarkable genetic trait in eukaryotes, particularly in plants. Most angiosperms experience one or more polypliodization events in their lineage. Although the frequent occurrence of this process suggests that there is an evolutionary advantage of having several sets of genetic material for adaptation, polypliodization events may induce genomic shock. Studies in numerous species have shown that silencing RNAs, especially microRNAs, small interfering RNAs, trans-acting siRNAs and natural antisense siRNAs, may act as «genetic buffers». Through silencing or over-activation of their target genes, the small RNAs influence decisively in most cellular processes involved in the functionality and stability of hybrids. In an innovative way, we analyzed the expression pattern of some microRNAs in coffee. The stem-loop RT-PCR assays with *Coffea arabica* tetraploid species and *Coffea canephora* diploid species, showed that the number of small RNAs corresponding to miRNAs increased according to the ploidy level. Evaluating the additive gene expression model, in *Coffea arabica* the chromosome number is  $2n = 4x = 44$  and the accumulation of microRNAs corresponded to approximately twice the values found for *Coffea canephora* ( $2n = 2x = 22$  chromosomes). In the case of allopolyploid, additive expression may provide the molecular basis required for compensation and balancing of the extra amount of redundant genes allocated in a single nucleus.

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## PB 266

NEW CYTOLOGICAL AND MOLECULAR DATA ON COFFEE-  
*COLLETOTRICHUM KAHAWAE* INTERACTIONS

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*Colletotrichum kahawae* is the causal agent of coffee berry disease (CBD), the most devastating Arabica coffee disease in Africa at high altitude, and represents an imminent threat for cultivation in America and Asia. In Kenya, the hybrid commercial variety, Ruiru 11, was bred for resistance to CBD and coffee leaf rust. Its female parent consists on lines of the cultivar Catimor (from Colombia) selected for resistance to both diseases in Kenya. One such line is Catimor 88, which is still being used in breeding programmes. Molecular studies using a F2 mapping population of the susceptible cultivar SL28 and the resistant line Catimor 88, identified and mapped a major gene (Ck-1) responsible for resistance to CBD.

In this study we aimed to start the cytological and molecular characterization of *C. kahawae* interaction with Catimor 88 vs a susceptible coffee variety (Caturra). When challenged with *C. kahawae*'s isolate Que2 (from Kenya), the majority of Catimor 88 hypocotyls presented scab lesions, whereas hypocotyls of the variety Caturra exhibited dark sunken lesions with sporulation, five to six days after inoculation. Light microscopic studies showed, in the susceptible genotype, the fungus growing without apparent inhibition and feeding on living host cells (biotrophy) before switching to necrotrophy. Reversely, in the resistant genotype fungal growth was frequently restricted to a single epidermal cell and plant response occurred early with accumulation of phenolic compounds and deployment of hypersensitive-like response (HR).

Gene expression studies using quantitative real time PCR (RT-qPCR) are currently being developed to characterize these interactions. This is a sensitive technique for quantifying gene expression, and its success depends on the stability of the reference genes used for data normalization. To our knowledge this is the first study on validation of coffee reference genes during *C. kahawae* infection time-course. Eight candidate reference genes (namely *ubiquitin* and *gapdh*) were selected and their expression stability is being evaluated by qRT-PCR in healthy and infected tissues of Caturra and Catimor 88, at 12h, 48h and 72h after inoculation. NormFinder and geNorm algorithms will be used to select the appropriate reference genes. Validation of such qRT-PCR reference genes will be discussed as the basis for the following gene expression analyses regarding this pathosystem.

This work was financially supported by project PTDC/AGR-GPL/112217/2009 from Fundação para a Ciência e a Tecnologia (Portugal).

## PA 100

### SOIL FERTILITY EVALUATION OF COFFEE (*Coffea canephora*) PLANTATIONS OF DIFFERENT AGES IN IBADAN, NIGERIA

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A study was carried out to investigate the nutrient status of coffee plantations of different ages, viz. 6 years, 19 years, 37 years and 42 years. Each coffee plantation was divided into four blocks. Soil samples were collected at soil depths of 0-15cm, 15-30cm and 30-45cm from five different points within each block. The soil samples collected were processed and analyzed for some of their physical and chemical properties. Plant samples taken from the coffee plants were also processed and analyzed for some of their chemical properties. Results indicated that the nitrogen content of the coffee plantation ranged between 0.9-2.4g/kg for 0-15cm soil depth, 0.7-1.3g/kg for 15-30cm soil depth and 0.6-1.2g/kg for 30-45cm soil depth. This was above the soil critical level of 0.9g/kg required for coffee. This is reflected in the high nitrogen level of the coffee leaf 1.56-2.0%, which is higher than the foliar critical level of 1.10% required for coffee. Soil phosphorous was also adequate across the coffee plantations irrespective of age, with phosphorous content ranging between 18.45-22.65mg/kg soil. This was well above the soil critical level of 6mg/kg soil required for coffee. Similar high phosphorous content of 1.1%-1.37% was observed on the coffee leaf. The potassium content of the soils across the coffee plantations ranged between 0.07-0.30cmol/kg. This was inadequate for coffee production. There is need to return potassium mined from the soil through guided fertilizer application to supply deficient K and enhance coffee production.

**PA 101**

**RESEARCH ACHIEVEMENTS ON COFFEE NUTRITION IN  
NIGERIA: CONSTRAINS AND FUTURE FOCUS**

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One of the most crucial factor in crop production is the suitability or otherwise of the soil. Coffee in Nigeria is basically cultivated on three major soil types viz Alfisol and Oxisol for Coffea canephora and Ultisol for Coffea arabica. Research findings over the years into various aspect of coffee production have provided bases upon which fertilizer recommendations have been based. Critical soil nutrient levels of 0.9g/kg N; 6mg/kg P; 0.40 Cmol/kg K; 0.9 Cmol/kg Ca and 0.8 Cmol/kg Mg has been established. While established critical values for foliar (fourth pair of leaves) are; 1.10% N, 0.07% P; 1.40% K, 0.37% Ca and 0.13% Mg. Results from various experiments indicates response to N and P. Phosphate fertilizers applied as Single Super phosphate (SSP) and Sokoto Rock phosphate (SRP) enhanced growth of coffee seedlings, while SRP had comparative effect on growth of coffee seedlings in the presence of mycorrhizal inoculation. Organic materials such as Chromoleana odorata, Pennesitum purpureum and cattle dung also enhanced growth of coffee seedlings. Coffee production in Nigeria receives little or no fertilizer and is in the hands of low income small scale farmers who produce without proper soil management practices. The decline in coffee price over the past years among other reasons has marred coffee production effort in Nigeria. This has lead to abandonment of coffee for more financially rewarding crops. The price of coffee beans in the international market is at all time high. For coffee farmers to benefit from this there is need to rehabilitate these abandoned coffee plantations with rehabilitation of the soil being critical. Adequate funding of coffee research in Nigeria is therefore essential to tackle soil and nutritional problems confronting coffee production in Nigeria.

**Keywords:** coffee nutrition, critical level

**PA 102**

**COFFEE DIVERSITY AT THE CROSSROAD IN AFRICA AND  
ENVIRONMENTAL SUSTAINABILITY**

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Africa is known as the centre of origin and genetic diversity for all coffee species produced worldwide. It is also one of the most vulnerable regions to global climate change. In most African countries, natural forest ecosystems with high levels of biodiversity are under serious threat, largely due to increasing population pressures and subsequent deforestation and land degradation. The destruction of natural coffee habitats coupled with changes in weather patterns can adversely affect coffee genetic resources and the livelihoods of millions of people in Africa and elsewhere. This paper deals with environmental preservation and coffee diversity in Africa, and takes into account opportunities and challenges in the face of global climate change and financial crisis. Sustainability includes environmental, social, and economical components, which are linked with importance and risks to the use of natural resources for development and human well-being. Special attention is given to the sustainable use and conservation of native coffee habitats and genetic resources for the future development and competitiveness of the coffee sector in Africa and globally. The diversity in coffee genes, species and ecosystems, traditional farming practices and technological innovations such as mitigation and adaptation strategies to climate change need to be exploited in the African continent to produce superior quality coffee types and remain competitive in the world market. The wild or cultivated coffee species/cultivars have specific ecological and input requirements to adapt and thrive in their places of origin and thus preserve diversity in Africa or in other coffee producing countries. This presentation provides a brief insight into the huge opportunities and challenges facing the environment and conservation of coffee generic resources in Africa. It draws conclusions about the need for urgent implementation of sound conservation measures to warrant the sustainability of healthy ecosystem services, development of the coffee sector and improving the living standards of people worldwide and in the African continent in particular as well.

**PA 103**

**A PARTICIPATORY AVIAN RESEARCH PROGRAM TO PROMOTE BIODIVERSITY CONSERVATION IN A COFFEE-PRODUCING LANDSCAPE**

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To achieve biodiversity conservation in rural landscapes, it is imperative to engage human communities as participating actors. Cenicafé, the research branch of the National Federation of Coffee Growers of Colombia, with the support of the U.S. Forest Service “Wings for the Americas” and The Nature Conservancy migratory bird conservation programs, has been conducting a participatory bird research program with groups of coffee growers to promote biodiversity conservation and sustainable development since 2004. This program entails conducting bird inventories with coffee farmers and their families in sites selected by the community in or near their farms; a creative and flexible educational program on bird identification, ecology and conservation, that adapts to the interests and needs of the community; and the production and distribution of educational bulletins and posters in a format and language accessible and attractive to young and adults. To ensure the participatory nature of the program, efforts are made to involve the community in the planning process, to create opportunities to discuss the regional significance of the results of bird inventories, and to encourage and support local conservation initiatives.

After seven years, 31 groups of coffee producers, their families, and in many cases, the local extension officers, have conducted bird inventories in 37 coffee-producing localities throughout the country. As a result of the inventories, the ornithological frontier in coffee producing regions of Colombia has been significantly extended: more than 500 species of birds have been observed, including 31 migrants and 26 endangered taxa.

More than a hundred workshops on a diversity of environmental topics have been conducted with the participation of members of the communities; and more than a hundred thousand copies of educational bulletins and posters have been given out. Several regional conservation initiatives have been supported and advised, such as the development of a management plan for oak-forest remnants that protect watersheds that benefit coffee producing communities; the implementation of several environmental education programs; and the design and implementation of a participatory program that aims to monitor the effects of conservation areas and corridors on bird communities. The program has also supported the formation of eight local groups of bird watchers, and provided them with binoculars, bird guides and training. These groups have carried out their own research, education or conservation project.

A formal evaluation of the effects of this program on conservation knowledge, attitudes and behaviors of coffee farmers indicated that participatory programs have the potential to promote biodiversity conservation and environmental sustainability and to encourage community autonomy to act on local conservation issues in rural areas.

**PA 104**

**ECONOMIC ANALYSIS OF INCREASING RESILIENCE OF COFFEE PRODUCTION TO LEAF RUST DISEASE IN INDIA**

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According to the Coffee Board of India, when the coffee leaf rust (CLR) is severe, loss foliage up to 50 per cent and berries up to 70 per cent can occur. Uncontrolled CLR disease, however, has negative impacts on coffee production, especially Arabica coffee that is more susceptible to CLR. This paper focuses on the economic analysis of increasing resilience of coffee production to leaf rust disease in India. Resilience is a process of positive capacity building of farmers/growers to cope with the CLR through effective management and thereby increase production and productivity. Hence, the economic analysis of CLR management has important implications on sustainable income generation and long term livelihood security of farmers, especially when their size and scale of production is small.

This paper is based on the newly collected primary data of 575 coffee growers (comprising 90 per cent of small growers with estate size of less than 10 hectares) in India in 2010. This sample is nationally representative by drawing the sample growers from all the traditional coffee growing states/regions.

Cost of management of CLR is estimated per acre of bearing area of Arabica coffee by input and labour costs. Input cost is estimated by market prices and recommended dosages of Bordeaux mixtures and systemic fungicides (e.g. Bayleton/Contof). Gross returns per acre of bearing area of Arabica coffee is estimated by adopters and non-adopters of recommended practices. Net welfare gains (or welfare gains net of cost of management of CLR) are estimated in terms of output increases by adopters of either or both of Bordeaux mixture and systemic fungicides.

The main result of this paper shows that, notwithstanding the remarkable differences between the costs and returns across states, the estimated net welfare gains for adopters are positive for all the growers. This provides with a strong empirical basis for promotion of recommended practices in order to target for higher production, exports and employment in India's coffee sector. In addition, based on the empirical results and insights from the sample survey, policy implications are derived on farmers' needs and capacity-building to cope with the CLR management.

This study reveals that greater professional interaction is needed between the coffee researchers in social, natural and life scientists to come out with holistic solutions on management of CLR and to translate scientific investments on research and development into measurable/estimable economic welfare. This paper is a small contribution towards such interactions from the viewpoint of economics as a social science.

To our knowledge, research studies on the economic impact of CLR in India and elsewhere are not available. Subject to the comparability of coffee farming conditions, prevalence and incidence of CLR and economic structures, the analysis and results of this paper are applicable and relevant to all CLR-affected coffee growing countries in the world.

**PA 105**

**MANAGEMENT OF ARABICA COFFEE FOR SUSTAINABLE PRODUCTIVITY IN ETHIOPIA: A REVIEW.**

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Forest soil is the best soil media for enhanced growth performance of coffee seedlings. However, for areas where forest soil is hardly available, alternative soil media composed of top soil (TS), compost (C) and sand (S) in 3:1:0, 2:1:1, 2:1:0, or 6:3:2 ratios or blends of organic manure (M) and top soil (TS) in 1:4, 2: 4 and 3:4 ratios resulted in vigorous seedlings. In media amendment study, application of 750 mg phosphorus alone or a combination of 2.31 g lime and 250 mg phosphorus per pot or seedling resulted in production of vigorous coffee seedlings. Provision of moderate level of over head shade (50% is the best) at nursery to coffee seedlings just after emergence and removal of mulch materials resulted in vigorous coffee seedlings with the highest total dry matter (TDM) yield and other growth parameters. Application of various mulch materials and cover crops not only control noxious weeds in coffee but also enrich soil fertility and thus help to produce best quality organic coffee in the country. Moreover, the productivity of coffee trees depends up on the effectiveness of different field management operations which are directly or indirectly related to coffee nutrition. Research findings reveal that intercropping coffee with locally adaptable and compatible cash and food crops is agronomically beneficial and economically feasible in south and southwest Ethiopia. Such crop diversification practices would enables to efficiently use resources like land and plant nutrients among others and minimize risk of crop failure due to biotic and abiotic stress. Therefore, depending on agro ecological suitability of an area, intercropping coffee with other compatible crops can be practiced as an important remedy to increase crop productivity and enhance economic returns of farming community, principally in the garden coffee production systems. Prominent shade tree species had significant effect on yields of Arabica coffee trees. The highest yield was obtained from coffee trees planted under *Millettia ferruginea*, *Acacia abyssinica*, *Albizia* spp., *Erythrina abyssinica*, *Calpurnea subdecondra* and *Cordia africana*. In addition the shade trees produced higher amount of litter fall and intercept moderate light intensities, ranging between 26 and 60%. Strip planting patterns of coffee and shade trees out yielded intercropped plots by 20.4%. Unlike intercropping, the advantages of strip cropping to minimize the direct competition between shade trees and coffee plants for the available resources, namely plant nutrients, moisture and light, have been emphasized in various studies. It is, therefore, concluded that productivity of coffee stands can be improved by growing coffee with optimum population density in strip between those prominent shade trees. The huge litter fall of leguminous coffee shade tree splices up on decomposition enrich the fertility of soil and enables the production of best quality organic coffee besides direct role in fixing atmospheric nitrogen.

## PA 106

## CULTIVATION OF PERENNIAL HERBACEOUS LEGUMES IN WEED MANAGEMENT IN COFFEE PLANTATION ON THE CERRADO

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The intercropping of legumes with coffee plants is an alternative practice for soil cover and weed management. The objective of this work was to evaluate herbaceous legumes cultivation on the weeds in coffee crops in the Cerrado (Brazilian savannah). The experiment was set up in a Catuai coffee crop at eight years of age and with a 3.80 x 0.70 m spacing. It was used a random block experimental design four replicates and ten treatments in a 4 x 2 + 2 factorial scheme, which was as follows: four legumes (forage peanut (*Arachis pintoi*); java hybrid (*Macrotyloma axillare*); perennial soybean (*Neonotonia wightii*) and wild ground nut (*Calopogonium mucunoides*)); two planting forms in the interrows of the coffee plantation with two and three rows of legumes spaced by 0.50 and 0.25 m, respectively. The two additional treatments consisted of hand weeding with a hoe and chemical control with glyphosate. Wild ground nut and forage increased soil coverage in the first and second year, respectively. Java hybrid maintained the greatest biomass yield in the two years, with the wild ground nut being the highest in the first year. The legumes decreased density and biomass of the weeds when compared with the additional treatments. Java hybrid, wild ground nut and forage peanut in the first year and java hybrid and perennial soybean, followed by forage peanut in the second year, decreased density and biomass of the weeds. Cultivation of two or three rows of legumes did not differ from each other in the evaluations. The cultivation of perennial herbaceous legume reduces the weeds of coffee plantation in the Cerrado.

## PA 107

HERBACEOUS LEGUMES INTERCROPPING IN WEED MANAGEMENT  
IN NEWLY PRUNED COFFEE PLANTATION

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Weed infestation in pruned coffee plantation is enhanced in the open and light-exposed interrows. The objective of this work was to evaluate soil covered with herbaceous legumes for reducing weeds in newly pruned coffee crop. The experiment was set up in Viçosa, MG, after the second pruning of a Catuaí Amarelo coffee plantation spaced by 3 x 1 m. It was used a random block experimental design with four replicates, made up by eight treatments in 3 x 2 + 2 factorial scheme: three legumes (forage peanut (*Arachis pintoi*), siratro (*Macroptilium atropurpureum*) and lablabe (*Dolichos lablab*)) and two planting forms in the interrows of the coffee crop and three rows of legumes spaced by 1.0 and 0.50 m, respectively. The two additional treatments consisted of hand weeding with a hoe and the chemical control with glyphosate. It was found that lablabe at 90 and 120 DAP provided the greatest soil cover, the greatest predominance of vegetation on the weeds and the smallest weed infestation. Both lablabe and forage peanut presented the highest biomass yield in the two years. Density and biomass of the weeds were reduced by lablabe and siratro in the dry period and with no difference between them in the rainy period in the first year and by forage peanut, with higher effect in the rainy period in the second year, respectively. Cultivation of two or three rows of legumes did not differ among each other in soil cover, in the weeds and in the coffee crop. There were no differences in soil moisture, plant height and in the first coffee yield among legumes plants and among the additional treatments. Herbaceous legumes intercropping reduces weeds of the newly pruned coffee plantation.

PA 108

**COFFEE BERRY BORER (*Hypothenemus hampei*)  
TRAPS ASSESSMENT****ROJAS, Mainor; ROJAS, Henry; GUERRERO, Giovanni; MORALES, Javier; DELGADO, Carlos****Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)**

The use of traps to monitor and control the coffee berry borer in Costa Rica is a recommended practice of integrated pest management. This practice has been embraced and its technology has been validated with very good results in the field, in the countries of the region. Between 2006 and 2011, four trials were conducted to assess the capture efficiency of different trap types, their contribution to pest control and maintenance cost reduction.

A randomized complete block design with at least five replicates (traps) was used per treatment, installing each trap in an area of 500m<sup>2</sup> and using the methanol+ethanol attractant in a 3:1 relation. The trap methods assessed were funnel traps (traditionally used in Costa Rica), crafty bottle trap, two dry capture prototypes, glue traps and the malathion impregnated tube to kill the coffee berry borer (tubo mata broca). The number of coffee berry borer insects captured per trap was calculated every two weeks in the water devices or at the end of every trial in the devices not using water as a trapping mean. Attack samplings at 90, 120 and 150 days after the main bloom, were conducted in the trials where the coffee berry borer killing tube was assessed, taking two samples of 100 fruits at random, per plot, from branches in similar age located at 5-6 m of the trap.

The results indicated that the captures from the disposable-bottle traps, the big funnel prototype without water and the glue trap were the same as those of the multiple funnel. However, the glue trap captured other types of insects, as well, such as Hymenoptera and Diptera, demonstrating that this is a not-specific trap. The trials assessing the attack in treatments with funnel traps and coffee-berry-borer killing tubes showed that none of the devices reduced pest damage significantly in relation to treatments without traps.

The bottle trap is a good option for small farms that can obtain the containers and give them the appropriate maintenance. The devices without water could be a good option for big farms, since they would be able to save in maintenance costs for big areas.

PA 109

EFFICIENCY OF *Beauveria bassiana* AS PART OF THE INTEGRATED PEST MANAGEMENT OF COFFEE BERRY BORER IN COSTA RICA**ROJAS, Mainor; GUERRERO, Giovanni; MORALES, Javier****Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)**

The entomopathogenic fungus *Beauveria bassiana* has proven to be one of the most important biological control agents of the coffee berry borer worldwide and has been incorporated as another element for integrated pest management in Costa Rica. Several trials for coffee berry borer management were conducted in different regions of the country between 2005 and 2011 using a preparation of *B. bassiana* native to Costa Rica with rice substrate and oil to evaluate its efficiency at the field.

Some of these experiments were located in Buenos Aires (2005), Orosi (2007), Barva (2008) and Santa Barbara de Heredia (2011), at 630, 1000, 1180 and 1225 m.a.s.l., respectively. A randomized complete block design with five replicates and plots of 12 plants was used. For each trial, 400 L/ha were applied when most of the coffee berry borer was located in the penetration channel, with a dose of  $1 \times 10^{12}$  spores/ha. Mortality was assessed at 15, 30 and 45 days after application through dissection of samples of 25-30 fruits damaged by the coffee berry borer per plot

In Buenos Aires, mortality increased after application, reaching a maximum peak of 27 percent after 40 days. In Orosi, the mortality data, corrected according to the test plot, showed a peak of 27.4 percent a month after application. The experiment in Barva included the application of the fungus produced by liquid fermentation prepared with oil and it was concluded that under monitoring conditions, related to the insect's position in the fruit, both preparations controlled more than 55 percent of the insects. By increasing the dose to  $5.5 \times 10^{12}$  spores/ha, mortality reached 82 percent with the rice preparation and 67 percent with the oil preparation. In Santa Barbara, the coffee berry borer mortality caused by the fungus increased up to 20 percent 40 days after application, having the same control level with both preparations.

**PA 110**

**INFLUENCE OF CLIMATE CHANGES ON THE COFFEE BERRY BORER (*Hypothenemus hampei*)**

**ROJAS, Mainor**

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The coffee berry borer is considered as the most economically serious pest in the cultivation of coffee, causing significant losses and increasing production and processing costs. Climate changes, mainly temperature and precipitation, affect the biological behavior of this insect. Temperatures ranging from 20°C to 25°C (68°F to 77°F) contribute to the highest rate for insect growth and fecundity, while multiple blooms stimulated by slightly marked dry periods facilitate their survival and reproduction. Climate change projections indicate that temperature will increase and there will be changes in rainfall patterns, affecting coffee growing and changing pest behavior.

This paper includes information generated for several years on the different conditions of coffee growing in Costa Rica including dry matter accumulation in fruits and its association to the coffee berry borer attacks and the start of the insect's reproduction, duration of the insect's life cycle at different heights, population dynamics in remaining fruits and behavior of the insect's flight in different regions. Potential effects of climate change on coffee growing in Costa Rica are analyzed, and management recommendations to be implemented are provided. This study concludes that although environmental conditions change, the principle of pest control should be focused on keeping smallest population possible, and that may be achieved through the integrated pest management practices that have been recommended.



**PA 111****ASSESSMENT OF ALTERNATIVE INSECTICIDES TO CONTROL THE COFFEE BERRY BORER (*Hypothenemus hampei*)**

**ROJAS, Mainor; ROJAS, Henry; GAMBOA, Adrián; OBANDO, Juan; GUERRERO, Giovanni; MORALES, Javier**

**Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)**

The chemical control of the coffee berry borer includes the use of insecticides when it is strictly necessary; consequently, it is important to find environmentally friendly products for sustainable coffee growing. Under this premise, research has been conducted on chemical products that are a good economic, environmentally friendly and efficient option for pest control.

Between 2005 and 2011, more than 10 field trials have been carried out in different regions of Costa Rica to assess insecticides. Having endosulfan as reference, the biological efficiency of the following insecticides was evaluated chlorpyrifos, fipronil, profenofos+lufenuron, fenitrothion, chlorfenapyr, cypermethrin, imidacloprid, thiacloprid, spinosad, ethiprole, pirimiphos-methyl and imidacloprid+deltamethrin.

In the trials, there was used a randomized complete block design with five replicates, plots of at least 10 x 12m and applications with a motorized mist blower when the coffee berry borers are penetrating the coffee fruits. The assessments calculated the mortality of coffee berry borers located in the penetration channel, through dissection of 30-40 fruits infected with the coffee berry borer per plot, at least twice after the application.

Results from different trials have indicated control levels between 60 and 80 percent for chlorpyrifos, 40-67 percent for fenitrothion, 50-80 percent for fipronil, 20-90 percent for thiacloprid and 30-40 percent for pirimiphos-methyl. The control levels in the other insecticides assessed were very low and have not differed from the treatment without application.

## PA 112

CRITICAL DENSITY of *Meloidogyne exigua* in ADULT COFFEE PLANTS

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The *Meloidogyne exigua* is the coffee root-knot nematode most commonly found in the Costa Rican coffee plantations, although its effect on the coffee yield is not clearly determined yet. This study aims at determining the critical density of *Meloidogyne exigua* in the adult coffee plants of the Caturra variety under semi-controlled field conditions.

The trial was conducted at the Center for Coffee Research (CICAFE), in Barva, province of Heredia, Costa Rica (24280 N and 521442 E Lambert Norte), at 1180 m.a.s.l., with a mean annual temperature of 21.5°C and a total annual rainfall of 2650 mm. Coffee plants of the Caturra variety formed in two axis, with a 2.0 x 1.0 m. planting distance, were planted in August 2009 in 100L pots with Dazomet-disinfected soil. A randomized complete block design with 10 replicates was used. The treatments were defined by the initial inoculum (Pi) of 125, 250, 500, 1000 and 2000 eggs +J<sub>2</sub> *M. exigua*/100 cm<sup>3</sup> soil, applied two months after planting. Adequate fertilization has been provided; in such a way that it would not be a limiting factor for development and production.

The plant development was evaluated in August 2010 and 2011 using height, stem diameter at the base, number of orthotropic nodes and branch length as indicators of each axis of the pot. Foliar samples were collected in September 2010, August and November 2011 for a complete chemical analysis of each plant. Soil and root samplings were collected in four blocks in September 2011, for the analysis of the *M. exigua* density. The 2011/2012 harvest was evaluated.

The evaluations of the four development variables showed no response to the initial inoculum of nematodes during the 2-year evaluation. The foliar analyses conducted in September 2010 and November 2011 indicated that the levels of elements were within the normal ranges and showed no response to initial inoculum of nematodes. However, the foliar analysis conducted in August 2011 showed a trend towards lower concentration of potassium and magnesium associated to the maximum initial inoculum. The J<sub>2</sub> *M. exigua*/100 g root reported a strong relationship with the initial inoculum and regression clearly separated the highest Pi ( $y = 0.0473x^2 - 36.776x + 78087$ ;  $R^2 = 0.9766$ ). This trial demonstrated a low density of *M. exigua* in the soil. There was no relationship observed between the first-harvest yield in kg/plant and the initial inoculum ( $y = 8.7E-05x + 7.06$ ;  $R^2 = 0.0016$ ).

## PA 113

CRITICAL DENSITY OF *Meloidogyne exigua* IN COFFEE NURSERY

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The purpose of this study was to evaluate the increasing density effect of *Meloidogyne exigua* on the development of nursery plants. In May 2009, coffee seedlings of the Caturra variety were transplanted in the cotyledon leaf stage of development, in two axes, in bags of 6» X 8» with 1335 cm<sup>3</sup> of substrate of soil + compost + rice chaff in a proportion 2: 1: 1 previously disinfected with dazomet to establish a trial with a randomized complete block design, with 11 treatments and 8 replicates. The treatments applied included initial populations (Pi) of 0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32 and 64 eggs + J<sub>2</sub>/cm<sup>3</sup> substrate applied one month after transplantation.

Height, stem diameter, number of orthotropic nodes and fresh weight were evaluated 200 days after inoculation. The model  $y = m + (1-m) Z^{P-T}$  applied to the height, diameter, number of nodes and fresh weight indicated that the tolerance limit (T) was 0.66, 0.06, 0.13 and 0.88 eggs + J<sub>2</sub>/cm<sup>3</sup> of substrate, respectively; the relative minimum yield (m) was 0.79, 0.79, 0.33 and 0.54 respectively, Pi equal to or higher than 64 eggs + J<sub>2</sub>/cm<sup>3</sup> substrate.

The gall index, density of nematodes in the root and the reproduction rate were clearly higher than the plant control based on a Pi of 0.125 eggs + J<sub>2</sub>/cm<sup>3</sup> substrate, while the density of nematodes in the soil was higher based on a Pi of 1 egg + J<sub>2</sub>/cm<sup>3</sup> substrate. The gall index reached its maximum based on a Pi of 2; the maximum of nematodes in the soil and roots was reached with a Pi between 2 and 4; the maximum reproduction rate was 57 based on a Pi of 0.125. It was concluded that the nursery should be free of nematodes, and that even with a low Pi, the maximum population can be reached in a short time.

## PA 114

THE COFFEE BERRY BORER (*Hypothenemus hampei*)  
CONTROL IN ROW PRUNING

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Assessments and a field trial were conducted with the purpose of studying the behavior of the coffee berry borer attack in plots with different pruning systems and validating the differentiated pest control in a row pruning system every three years. Samplings of the coffee berry borer attack were conducted during the rainy season in 2008 and 2009 in plots with different pruning systems in 29 sites of nine coffee growing locations of Costa Rica, including plots of 2-3 year total pruning and plots pruned per row every 3-4 years.

The field trial was conducted between May and August 2010 in a plot with row pruning every three years located in Pérez Zeledón. A paired t-test with seven replicates was used to compare the traditional insecticide application with the application only to the row with the oldest branches. Sampling of the initial attack was conducted per plot and age of row, before defining the insecticide application, assessing 100 fruits randomly taken per sample. After the differentiated application of the insecticide, assessments of the attack per plot and age of row were conducted at 30, 60 and 90 days after the application (DAA). At 90 DAA, 30 fruits infected with the coffee berry borer were dissected per plot and age of row to assess mortality.

The assessment of the coffee berry borer in sites where pruning is performed per plot every three years showed a reduction of 51 percent in the attacks to one-year plants in relation to the two-year plants. In plots where row pruning is performed every four years, attacks were 52 and 65 percent less in one and two-year plants than in three-year plants. A similar effect was observed in plots with row pruning every three years, where one-year plants had an average of 56 percent less attack than two-year plants.

In the field trial, the initial assessment showed that in average the three-year row was attacked by the coffee berry borer in 8.2 percent and the two-year row in only 2.2 percent, a significant difference of 73 percent. After the differentiated application, the percentage of fruits with coffee berry borers alive in the three-year row was of 0.7 percent in both treatments at 90 DAA, while in the two-year row this percentage was 0.7 percent where the insecticide was applied and 1 percent where it was not applied, and there were no significant differences between the treatments. The differentiated control of the coffee berry borer in a pruning system per row performed every three years made it possible to save 30 percent of application time, 40 percent of insecticide and 36.5 percent of water used for aspersion, by making the application only to the 33 percent of the coffee plantation and without putting into risk the rest of the area cultivated.

It was concluded that pruning per plot and per row makes it possible to concentrate the coffee berry borer in small areas of the coffee plantation, which contributes to pest control management and investment reduction.

**PA 115**

## ASSESSING THE RISK FROM PESTICIDE USE IN THE COFFEE INDUSTRY OF JAMAICA: A SURVEY OF THE KNOWLEDGE LEVEL, ATTITUDES AND PRACTICES OF KEY COFFEE INDUSTRY STAKEHOLDERS AS IT RELATES TO PESTICIDE USE AND SAFETY MANAGEMENT

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**\*Coffee Industry Board, Kingston, Jamaica.**

A cross sectional study was done to look at the knowledge level, attitudes and practices of coffee farmers and processors to determine if there was a risk to human and environmental health from pesticide use in coffee production. Data related to residual pesticides in coffee was also examined to look at risk to consumers of the final product.

The majority (89.3%) of coffee farmers surveyed utilizes pesticides in coffee production; approximately 15 active ingredients are being used in coffee production. The use of pesticides was significantly associated with the type of coffee grown ( $p= 0.000$ ). The use of PPE and the self-application of pesticides were significantly associated with level of production ( $p=0.014$ ;  $p= 0.004$ ). There was a significant association between owners trained in pesticide use and knowledge of health effects of pesticides ( $p= 0.001$ .)

Although hygiene and sanitation practices at the processing level greatly reduce the possible contamination of the final product, the detection of residual pesticides in green coffee beans suggests that there still remains a potential for contamination of the product due to poor post-harvest transportation, storage and handling. Results of pesticide residues were found in green coffee samples at levels up to 250-500 times the Japanese and CODEX MRLs.

The findings of this study suggest a significant risk to farmer and farm workers from exposure to and handling of pesticides at the farm level. There is also potential contamination of environmental media, including water bodies, from activities such as washing of equipment in rivers and streams, overuse and pre-emptive application of pesticides. Training intervention in safe pesticide use is required at all levels of coffee production; integrated pest management strategies should be promoted to reduce reliance on chemical pest control. The current Environmental Codes of Practice for the coffee industry should also be updated to include best practices related to agrochemical use and management. Continuous end point testing is also necessary to protect the health of consumers from residues of pesticides at levels which may be hazardous to human health.

**PA 116****FIELD EFFICACY OF SELECTED PESTICIDES AGAINST THE COFFEE BERRY BORER, *Hypothenemus hampei* (FERRARI), IN JAMAICA****DRYSDALE, Laurence\*, ROBINSON, Dwight E.\*, McCOOK, Gusland\*\*, BRYAN, Gerald\*\***

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Coffee Industry Board, Kingston, Jamaica.

The Coffee Berry Borer (CBB), *Hypothenemus hampei* (Ferrari) (Curculionidae Coleoptera), has been a major pest of coffee in Jamaica since its presence was discovered in 1978. Since then, endosulfan has been the insecticide of choice for the chemical control of the pest. However, after being used in Jamaica for almost 30 years, its importation into Jamaica has now been banned creating a need to find an alternate insecticide. The present study was designed to assess the field efficacy of four insecticides against a selected population of *H. hampei*.

The study was conducted on a 0.33 hectare plot of coffee in St. Catherine, Jamaica. Five insecticides, Danitol-S and Danitol-S-Ultra (Active Ingredient: Fenitrothion, Fenpropathrin), Karate (Active Ingredient: Lambda Cyhalothrin), Trigard WP (Active Ingredient: Cyromazine) and Actara (Active Ingredient: Thiamethoxam) were used to treat selected plots and the level of CBB infestation, bean damage and CBB mortality were assessed before and at regular intervals after treatment.

Over the 37-day post-treatment period, plots treated with Danitol-S-Ultra had an overall decline of 4.5% in CBB infestation, while infestation in plots treated with Karate, Danitol-S, Trigard & Actara and the control increased by 0.9, 1.6, 3.6 and 4.1%, respectively. Changes in the level of bean damage observed in the experimental plots were not significantly different ( $P > 0.05$ ). Mortality of the CBB in infested berries was generally low, ranging from 4.1% in plots treated with Danitol-S-Ultra to 13.3% in the control.

**PA 117****A SURVEY OF THE SOCIO-AGRONOMIC PROFILE AND  
PRODUCTIVITY OF COFFEE FARMS IN JAMAICA DURING THE  
2008-2009 CROPPING SEASON****McCOOK, Gusland\*, ROBINSON, Dwight E.\*\*****\* Coffee Industry Board, Kingston, Jamaica, \*\* Department of Life Sciences, The University of the West Indies, Mona, Kingston 7, Jamaica.**

Since the 1940s, the Jamaican coffee industry has continually contributed to the gross domestic product of Jamaica and provides employment for persons living in the mountainous regions of the country, where coffee cultivation is the major economic activity. Person from different sociological backgrounds participate in the production of coffee in Jamaica and it is often suggested that the variations in agronomic practices and hence the levels of productivity may be impacted by the socio-economic and cultural background of the farmers. The current study was designed to conduct a preliminary assessment of the socio-agronomic profile and productivity of coffee farms, selected at random from coffee producing areas across Jamaica, during the 2008/09 production season.

Of the 100 farms surveyed, only 20% were owned or managed by females with 59% of the farmers being above the age of 50 years. The mean farm size was  $2.9 \pm 1.4$  hectares with a mean production of  $59.6 \pm 7.95$  boxes of coffee per hectare. The mean loss of harvested coffee at floating was  $17.0 \pm 1.7\%$ . There was no correlation ( $R^2 = 0.012$  and  $0.001$ , respectively) between the age of the farmers and the level of productivity or loss at harvest. Ninety-eight percent of the farmers attempted an integrated approach to the management of the coffee berry borer, of which 63% were still using endosulfan as part of a chemical control programme. Sixteen percent of the farmers used no insecticides as part of their berry borer management programme.

**PA 118****STUDY ON ARABICA COFFEE FRUIT PHENOLOGY AND BEAN SIZE IN RELATION TO AGRONOMIC PRACTICE.**

**ALEMSEGED, Yilma\***, **TESFAYE, Shimber** and **ENDALE, Taye**  
Ethiopian Institute of Agricultural Research, Jimma Research Center,  
P. O. Box 192, Jimma, Ethiopia.

Commercial coffee is processed and packed as green beans for various purposes, such as for processing, trade, and house hold use. Coffee bean size is primarily affected by its genetic characteristics, cultural practices applied and environmental factors.

Study on coffee fruit phenology and bean size in relation to different agronomic practices was conducted at Melko Jimma research centre using CBD resistant varieties for two cropping season.

Significant ( $p \leq 0.01$ ) variation was observed between phenological stage of coffee fruit weight (fresh and dry) and estimated volume (length x breadth x Depth) during the growing weeks after anthesis. Generally, there exists two alternating and sinusoidal behavior i.e. very little growth (weeks 0-8), linear expanding (weeks 9-15), static, (weeks 16-25), sigmoid stage (weeks 26- 32) and gradually decreasing growth and maturity stage (weeks 33-37).

On the other hand, open varieties had maximum value for both fruit and bean weight and volume. Bean size ( length, breadth, depth) of the varieties are also affected by number of bearing heads per tree, fruit proximity on plagiorthropic branch to words orthotropic main stem, branch age, shade, density and canopy classes.

It is speculated that genetic, seasonal climatic change and management practices dictate coffee fruit and bean size. Therefore, it is quite convincing that knowing the phenology of coffee fruit and factors affecting bean size would help to determine the optimum rate of nutrient application and irrigation scheme at time of stress and control berry drop, quality affecting factors and biennial bearing habit of trees.

**PA 119**

## **COFFEE TREE PRODUCTIVE CENTRE POTENTIAL AS AFFECTED BY DIFFERENT TRAINING AND PRUNING PRACTICE.**

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Coffee pruning is essential to stimulate the production of new wood and maintain the tree at a manageable size. Pruning controls the shape and the height of the tree, which affects picking, while controlling the following year's crop. Selection of a pruning strategy requires information of how pruning will have an effect on the tree and give sustainable production. On contrary unpruned trees produces bigger size of stem, more suckers, and large numbers of smaller fruiting branches.

An experiment was carried out with the objective of evaluating the coffee tree productive centre by training and pruning practices. Four treatments i.e. single stem topped, two stem topped, two stem free heights and free growth were tested on open and compact canopy classes in RCBD design with three replications at Melko –Jimma research center. Topping was done at 2.20 meter.

There was a marked difference between training and pruning treatments for productivity of productive centre. 96 and 94% of the primary branch is out of production in single stem and two stem topped treatment followed by 64 and 57% in two stem free height and free growth, respectively, after six consecutive productions.

The bearing surface for free growth and two stem free height were 21and 14% and new (current) growth was 21and 20% respectively on the 6<sup>th</sup> potential cropping season. No new growth of primary branch in the productive centre was found for the topped single and two stem training treatments at this time. In general, all primary branches gave significant crop only for three years, while secondary's for two years during the study period.

In relation to this feature, free growth out yielded and gave 2200 and 1800 kg/ha for open and compact canopy classes respectively. This is because of the contribution of newly growing bearing heads to subsequent potential crop of the trees.

There fore, hard pruning during the first six harvests reduces the bearing surface and leads to proportionally higher productivity losses. The free growth or no pruning system seems to be a more economic benefit under condition similar to Jimma- Melko..

**PA 120**

**FERTILIZATION ASSESSMENT IN THE  
PRODUCTION OF PLANTLETS IN BAGS**

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A trial was conducted in the Experimental Station of the Costa Rican Coffee Institute (CICAFE), located in Barva, province of Heredia, Costa Rica, at 1100 m.a.s.l., to assess the different formulas of conventional and slow release fertilizers to be used in the production of plantlets in bags. Twelve 15 x 20 cm polyethylene bags were used in the plot, each one planted with two seedlings of the Catuí variety. The substrate used for filling the bags was a mixture of soil, shrub and rice chaff in a 2-1-1 volumetric relationship. The planting date was May 5, 2009 and the trial concluded with the measurement of the dry weight of the aerial part and the roots of the plants eight months after the starting date. A randomized complete block design with six replicates was used. Six treatments were evaluated: a control without fertilizer, Osmocote 18-6-12 (10 months), Basacote 16-8-12-2+ME (9 months), Entec® Blue Special (12-12-17), Hydrocomplex (12-11-18-3 + ME) and a relative control treatment alternating DAP and F.C. 18-5-15-6 -2 B. The slow-release fertilizers Osmocote and Basacote were applied at a dose of 6 g/plant, in one application, using a digging-stick, 42 days after planting the seedlings. For the remaining treatments, there were seven applications of fertilizer, at a dose of 2.5 g/ plant. The first application was made 42 days after the seedlings were planted; the following applications were made approximately every 30 days. In the relative control treatment, the first two applications were of DAP and the rest was F.C. 18-5-15-6.2 (chemistry). The traditional treatment showed the highest aerial biomass; there were no statistical differences from Basacote and Entec® Blue, but differences were observed in relation to Hydrocomplex and Osmocote. The main root biomass was obtained with Basacote, which significantly exceeded the other treatments, except for the traditional treatment. In addition, the absolute control treatment was clearly the one with the lower growth in both, the root and the aerial part. Thus, in fertilizers that are to be applied in splits, the Traditional treatment (DAP + F.C. 18-5-15-6-0.2) was the best option (better development of plants and lower product cost), while in the slow release fertilizers Basacote reported better performance.

## PA 121

CHARACTERIZATION OF FERTILITY IN SOILS DEVOTED TO  
COFFEE CULTIVATION IN THE PEREZ ZELEDON REGION

**CHAVES, Víctor\*; CHAVARRÍA, Jesús\*, GUZMÁN, José\*, ALPÍZAR, Yorleny\*, NUNES, Aisha\*, VARGAS, Henry\*.**

\*Instituto del Café de Costa Rica

In order to characterize the coffee soil fertility in the Perez Zeledon region, between December and March 2008-2009, the coffee area of this region was systematically sampled. The following districts were included: Cajón, Daniel Flores, General, Pejibaye, Platanares, Páramo, Rivas, Río Nuevo, San Isidro del General and San Pedro (canton of Perez Zeledon, province of San José), and Boruca, Brunka, Buenos Aires, Colinas, Pilas, Volcán and part of Potrero Grande (canton of Buenos Aires, province of Puntarenas). Aerial photographs were used for selecting the collection sites. A grid with a density of one site every ten hectares was superimposed on the aerial photographs; every site was appropriated geo-referenced. A total of 1364 samples (equivalent to 13640 ha planted with coffee) were collected. Each sample was formed from six subsamples taken on the band of fertilization, at a depth of 0-20 cm, in a radius of approximately 10 m within the geo-referenced site. The water pH, interchangeable soil acidity (IA), Ca and Mg extracted with 1N KCl, and K, P, Cu, Zn, Mn and Fe with Modified Olsen were determined for each sample. According to the parameters established, at the regional level, of all samples 89 percent showed low pH, 69 percent showed high AI and the percentage of samples classified as low for each element was: Ca 73 percent, 72 percent Mg, K 38 percent, P 70 percent, Zn 39 percent, Mn 22 percent, Fe 0 percent and Cu 3 percent. In addition, this paper provides the results for each variable classified by district, fertility maps using the Arc-Gis 9.2 program and recommendations for fertilization programs.

## PA 122

## ASSESSMENT OF COFFEE INTERCROPPED WITH MAIZE

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With the purpose of assessing the profitability of a system of coffee intercropped with maize in establishing plantations and its effect on the development of coffee plants, a trial was conducted on Andisols, at 1150 m.a.s.l., in the experimental farm of ICAFE (CICAFE) located in San Pedro de Barva, province of Heredia, Costa Rica. The study began with the planting of coffee trees on July 8, 2008, using the Catuaí variety in full sunlight, in two axes per planting hole, at a density of 5884 trees/ha (1.90 x 0.90 m). The assessment included three coffee-maize relationships and an indicator coffee plant in a monoculture. In the first relationship, maize plants were planted at a proximity of 15cm from each coffee plant. In the second relationship, maize plants were planted in the center of the alley, forming a single row, at a distance of 50 cm between plants. In the third relationship, two rows of maize were planted in each alley. The maize was planted on July 11 using a digging-stick, dropping three seeds per hole, which later was thinned to two plants. The maize planting density for each relationship was 11,688, 21,040 and 42,080 plts/ha respectively. Three fertilization applications were made to the maize plants in the second and third relationships; and one fertilization application was made to the coffee plants in the first relationship. Corn was harvested 108 days after planting. The profit (cost-revenue) for treatments 1, 2 and 3 was ₡435,785, ₡418,435 and ₡1,211,201 respectively and, in the same order, the benefit/cost relationship ₡2,67, ₡1,58 and ₡2,18. No harmful effects of the maize on the plant development of the coffee trees or on the initial harvest were found. Under conditions similar to those of the study (management, soil, climate, etc.), the coffee-maize relationship seems as a good choice for establishing coffee plantations, as this would not affect the development of the coffee plants; in contrast, it would mean an income in a period in which the coffee trees are not ready for harvest.

## PA 123

## LIMING ASSESSMENT. CORRECTION OF SOIL ACIDITY IN AN ANDISOL

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With the purpose of evaluating the effect of different calcareous amendments on the acidity correction of an Andisol, a trial was conducted in ICAFE's experimental station (CICAFE), in San Pedro de Barva, province of Heredia, at 1100 m.a.s.l., in a coffee plot in full sunlight, with total pruning in February 2007. The treatments were applications of Calcium Carbonate, Dolomite, Hi-Cal-Mag, Triple Cal®, Surco Mejorador®, Nutrical and Tgsa Mag. The Calcium Carbonate and Dolomite were applied at a dose of 1.50 t/ha and the other five products at 0.75 t/ha. There was an eighth treatment: a control without liming. A randomized complete block design with five replicates was used in each one of the two sampling periods. The products were applied on the surface, spread over the alley, on September 12, 2008. After 236 and 426 days from the application of treatments (DAA), soil samples were taken at six depths (0-8, 8-16, 16-24, 24-32, 32-40 and 40-48 cm).

Those samples were used to analyze the pH in water, exchangeable acidity, Ca and Mg extracted with 1N KCl; and K, P, Cu, Zn, Mn and Fe extracted with Modified Olsen. When examining each of the sampling depths individually, in terms of the parameters more related to soil acidity, such as pH, exchangeable acidity and acidity saturation percentage, significant differences were only found in the surface horizon (0-8 cm), and for the three variables the Calcium Carbonate was the one showing the highest acidity correction, differing statistically from the control treatment. When examining the sub-surface horizons (8-48 cm) together, the Dolomite and the Calcium Carbonate reported the highest acidity correction at 426 DAA, and they were the only ones differing statistically from the control treatment in terms of pH, exchangeable acidity and acidity saturation percentage.

**PA 124****FERTILIZATION PROGRAM ASSESSMENT****CHAVES, Víctor\***

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In order to evaluate alternative fertilization programs to reduce production costs temporarily, a trial was conducted in an Andisol of San Rafael de Poás, province of Alajuela, Costa Rica, at an altitude of 1450 m.a.s.l., in a plot of the Catuaí variety. The treatments were applications of the traditional complete formula (18-5-15-6-0.2B) in two doses (900 and 450 kg/ha, supplemented with an extra-nitrogen formula of 254 and 127 kg/ha Ammonium Nitrate respectively) with and without adding 350 kg/ha of the pellet calcareous amendment (Granumax™). The fifth treatment was the application of 550 kg/ha of the complete formula 30-0-10-5-0B (FR) supplemented with 254 kg of Ammonium Nitrate/ha. The trial started in the second fertilization period of 2008 (August) and two harvest periods (2009/2010 and 2010/2011) were evaluated. A randomized complete block experimental design with seven replicates and a factorial arrangement  $4 \times 2 + 1$  was used. In the average of both harvests, although the treatments with the lower doses of the traditional formula were those of lower production, the differences were not statistically significant compared to the other treatments. In the factor analysis (excluding the FR treatment), no interaction was found between the dose of the traditional complete formula and the use of Granumax; individual effects were then analyzed. In relation to the dose, no significant difference was found in the 2009/2010 harvest; however, in the next harvest, the higher dose exceeded the production of the lower dose in 40 percent. According to the statistical analysis, no significant effects were found in the Granumax application in the harvests evaluated, or in their average. The study concludes that the application of the pellet calcareous amendment increased the costs without showing positive results on the production; therefore, it was not a good strategy to replace the traditional fertilization management. On the contrary, when comparing it to the treatment of the higher dose of the traditional complete formula, the fertilization with the FR formula showed similar production at a lower cost. This means that under conditions similar to those of this trial, it becomes an attractive alternative to be used for short periods when it is necessary to reduce the use of fertilizers.

**PA 125**

**VERIFICATION OF DIFFERENT FERTILIZER FORMULATION  
FOR SUSTAINABLE PRODUCTION OF COFFEE SEEDLING  
GROWTH IN ETHIOPIA**

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Fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of di-ammonium phosphate (DAP) and Urea for almost all cultivated crops for both market and food security purposes for the last several years. The objective of this verification trial was therefore, to evaluate the effectiveness usage of the different fertilizer formulations for its roles in reduction of chemical fertilizers for sustainable use. Different Compo products have been recognized as inorganic fertilizer sources consisting of many macro and micro-nutrients in a single formula. These new Compo products *viz.* Bascot Plus®12M, Bascot LR®, Solugran 17-9-20 and Fetrlon Combi ® have been tested under nursery at Jimma and Mettu Coffee Research Center using coffee as a test crop, in 2010. The results of the investigation revealed that growth of coffee seedlings evaluated by non-destructive (plant height, stem diameter, and number of primary branches and leaves), and destructive (leaf, stem and root fresh and dry weight, tap and lateral root length and lateral root number) growth parameter was significantly ( $P \leq 0.01$  or  $P \leq 0.01$ ) affected by different fertilizer treatments at Jimma and Mettu. At Jimma the highest response of the aforementioned growth parameters were recorded from coffee seedlings treated by DAP and followed by Basacote® Plus and Basacote® LR. However, there was no significant growth variation among seedlings that were treated with Solugran 17-9-20. Seedlings grown using the Fetrlon Combi®, recommended media and control showed the lowest values of seedling growth at both locations. In general, the result obtained for this study showed that the current fertilizer recommendations for coffee using DAP gave better seedling growth at both locations compared to the new fertilizers. Among the introduced four new fertilizers Basacote® Plus and Basacote® LR has a promising results and need further investigation.

Key word: New fertilizers, DAP, coffee seedling growth

**PA 126**

**EVALUATION OF SELECTIONS OF CULTIVAR BOURBON  
AMARELO IN SÃO SEBASTIÃO DA GRAMA-SP.**

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The cultivar Bourbon Amarelo is result of a natural mutation of cv. Bourbon Vermelho or natural crossing between cvs. Bourbon Vermelho and Amarelo de Botucatu (Típica Amarelo). Selected and released by the Instituto Agronômico de Campinas (IAC) since 1945. Its productivity is less than a number of other cultivars, but is recommended for producing special coffee, because of their excellent qualities of beverage. However, there is little information on the agronomic performance of crop in the main coffee growing regions of Brazil. The objective of this study was to analyze the behavior of this variety of coffee, looking for answers more precise on the genotype-environment interactions in relation to productivity and characteristics of the seeds. For this experiment were 34 selections from cultivar Bourbon Amarelo developed at the IAC. For this purpose, the experiment was conducted in a randomized block design with three replications and ten plants per plot in São Sebastião da Gramá - SP. In the period 2008 to 2011, productivity was measured in bags of green coffee per hectare, the percentage out-turn and seed characteristics (percentage of grain the types of flat, peaberry and elephant beans, mass of 100 seeds and sieve average) of the selections analyzed. In the experiment, were the most productive Bourbon Amarelo IAC J 13-08, Bourbon Amarelo IAC J 08-02 and Bourbon Amarelo IAC J 19-18-10, with yields of 25.5, 23.5 and 22.8 bags of green coffee per hectare / year, respectively. The quality of the beverage was analyzed by SCAA and obtained results about 80.0 to 83.0 points.

**PA 127**
**CULTIVAR IAC OBATÃ AMARELO, A CONTRIBUTION OF AGRONOMIC INSTITUTE OF CAMPINAS FOR BRAZILIAN COFFEE**

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The aim of this study was to obtain a cultivar of arabica coffee, short stature, with resistance to rust and yellow fruits. After several years of studies at the Instituto Agronômico de Campinas obtained the IAC Obatã Amarelo. It originated in a natural crossing of a coffee cultivar with another Obatã IAC 1669-20 coffee cv. Catuaí Amarelo, occurred in an experiment established in Garça - SP. Seeds from the original plant Obatã IAC 1669-20, plant 16B, this experiment were removed in 1984 and obtained plants were selected and planted in various locations. Were identified in segregating generations, plants with yellow fruits with the same characteristics of the cultivar IAC Obatã 1669-20. The progeny selected in F6, short stature, yellow fruits and rust resistance has been designated by IAC Obatã Amarelo. The principal characteristics are reported below:

IAC Obatã Amarelo	
Plant height	Short
Canopy	Cylindrical-conical
Canopy diameter	Average
Internode length	Short
Branch plagiotropica	High
Color of young leaves (shoots)	Green
Size of heet	Large
Color of ripe fruit	Yellow
Fruit size	Large
Fruit shape	Oblong
Size of the seed	Large
Format seed	Short and wide
Ripening period	Late
Waving leaf edge	Little wavy
Resistance to rust	Resistant to Moderate resistant
Resistance to nematode	Susceptible
Strenght	High
Quality of the drink	Good
Productivity	High

The average productivity in the six years of consecutive harvests, in an experiment without irrigation Garça - SP, was 37.5 bags of green coffee per hectare / year, while the cv. Catuaí Amarelo IAC 62, used as a control, was 36.4 bags / ha / year. IAC Obatã Amarelo is indicated mostly for plantations with irrigation and fertilizers, irrigation, it is demanding in nutrients and water. Being resistant to rust, its use allows for less spending on fungicides, presents considerable savings for the producer giving more profit and financial stability, reduction of environmental pollution (soil and groundwater) while preserving the environment, reducing the risk to the health of applicators of the product and growers. It is therefore, in line with the growing demand for cultivars that use fewer chemicals. This cultivar is also important for the family and organic coffee.

**PA 128**

**DETERMINING NUTRIENT COMPOSITION OF NPK FERTILIZER  
APPLIED ON COFFEE BASED ON THE NUTRIENT REMOVED IN  
YIELD AND SEASONAL PHENOLOGY**

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The purpose of fertilization on coffee plants is to replace the nutrients removed in harvested yield and to fulfill nutrient needed by plants those are follow the seasonal phenology as well as plant development phases. Nutrients those are removed by arabica coffee cherries that equivalent to one tonne of green beans were about 64 kg N, 12 kg P<sub>2</sub>O<sub>5</sub>, and 68 kg K<sub>2</sub>O, while in robusta coffee were about 36 kg N, 6 kg P<sub>2</sub>O<sub>5</sub> and 50 kg K<sub>2</sub>O. Seasonal phenology of coffee that are consisted of flower primordia formation phase, the blossoming, the development and filling of cherry as well as seed is influenced by the latitude and the distribution of rainfall in the planting area. Hence, the nutrients needed by coffee crops also follow the phases of the seasonal phenology. On the phase of flower primordia formation and blossoming required more P element than K, while the phase of cherry as well as seed development and filling are more K needed rather than P. The need of N element is relatively same in all the seasonal phenological phases. In coffee producing areas in Java (Indonesia, 5-8°S of latitude), the phase of flower primordia formation and blossoming occurs in the second half of the year (July-December), that are overlap apartly with period of the rainy season (November-April), while the development of cherry as well as seed and the filling phases occurs in the first half of the year (January- June), that are overlap partly with period of the dry season (May-October). Fertilizer application is done twice a year to meet the optimum availability of water as a solvent for fertilizer, those are in the second half of the year (the beginning of the rainy season, November-December) and in the first half of the year (the end of rainy season, March-April). Based on the nutrient requirements in each phase of the seasonal phenology, the fertilizer needed by coffee plant in the second half of the year (November-December) consists of a half dose of N + full dose of P, whereas in the first half of the year (March-April) consists of a half dose of N + full dose of K. If it is assumed that the average productivity of coffee plants as much as 1 tonne per hectare of green coffee, the minimum dose and composition of nutrients that should be applied in the form of fertilizer for arabica coffee in the second half of the year is 32 kg N/ha and 12 kg P<sub>2</sub>O<sub>5</sub>/ha, while in the first half of the year is 32 kg N/ha and 68 kg K<sub>2</sub>O/ha. With the same assumptions, the minimum dose and composition of nutrients that should applied in the form of fertilizer for robusta coffee in the second half of the year is 18 kg N/ha and 6 kg P<sub>2</sub>O<sub>5</sub>/ha, whereas in the first half of the year is 18 kg N/ha and 50 kg K<sub>2</sub>O/ha.

**PA 129**

**SPATIAL DISTRIBUTION OF COFFEES FROM MINAS GERAIS STATE  
AND THEIR RELATION WITH QUALITY**

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Coffee is the second most important agricultural exportation product in Brazil, constituting one of the main income sources of the Brazilian economy. The state of Minas Gerais is the country's biggest coffee producer. Recently, coffees produced in the state have won national specialty coffee contests, which has increased their commercial value and established them in the market. Due to the necessity of more information on areas with potential for producing quality coffee, the objective of this work was to relate the sensorial quality and

trigonelline, caffeine and 5-cafeoylquinic acid content of the coffees entered in the Quality Contest- Coffee from Minas Gerais, in 2007, with the environmental characteristics of the state's districts. The samples were distributed in four stages, the first composed of all the coffees entered in the contest, and the last composed only of the pre-finalists. The samples were categorized into natural and pulped natural. The correlations between environmental factors, chemical compounds and sensorial quality were done through Principal Component Analysis and Biplot graphs. 60 coffees were selected, 30 natural and 30 pulped natural, 15 with scores over 80 and 15 with scores under 75 points, according to the BSCA methodology for sensorial analysis of the coffee beverage. The results showed high and low scores due to environmental variables, the chemical compounds analyzed and the sensorial quality. Geostatistical studies of the 2007 samples showed, through semivariograms, that the models tested adjusted to the data studied. The data from the 60 selected samples did not present model adjustment. However, the results are still a relevant contribution, as they point out new paths for future works on the spatialization of coffee quality in Minas Gerais.

**Keywords:** Specialty coffee, sensory, latitude, altitude and quality.

## PA 130

### CULTIVARS APPROPRIATE FOR IRRIGATION: OBATÃ IAC 1669-20 AND IAC OBATÃ AMARELO

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The arabica coffee cultivars, Obatã IAC 1669-20, with red fruit, and IAC Obatã Amarelo, with yellow fruits, are very productive, rust resistant and have been planted and evaluated under rainfed conditions, irrigation and ferti-irrigation. The present study aims to evaluate these cultivars in the cropping system ferti-irrigated and rainfed conditions in the cities of Gália and Garça, São Paulo State, Brazil, respectively. The cultivar IAC Obatã 1669-20 is derived from the cross of cv Villa Sarchí with the Timor Hybrid (CIFC 832/2), which generated the F1 hybrid (H361 / 4), conducted by the Centro de Investigação da Ferrugem do Cafeeiro/CIFC (Research Centre of Coffee Rust), in Oeiras, Portugal. The F2 coffee trees obtained from this hybrid were planted in 1971 in Campinas, SP, with good yields. Progenies of selected trees were evaluated in various experiments and therefore the selection continued for several generations. The cultivar IAC Obatã 1669-20 is likely a result of natural hybridization of a coffee H 361/4 with the cultivar Catuaí Vermelho. The cultivar IAC Obatã 1669-20 was officially launched by IAC in 2000 and registered on the National Register of Cultivars (RNC), in 1999. It is a cultivar that is resistant to rust, late maturing, and in some regions, later than the actual Catuaí Vermelho. IAC Obatã Amarelo likely originates from a natural crossing the cultivar Obatã IAC 1669-20 with Catuaí Amarelo, occurred in Garça-SP. The progeny derived from the cultivar Obatã presenting yellow fruits and resistance to rust was designated IAC Obatã Amarelo. Two experiments with arabica coffee were installed, one without irrigation and other on ferti-irrigation. The variety with highest yield in the experiment was ferti-irrigated Obatã IAC 1669-20, with 76.9 bags / ha / year, not differing from IAC Obatã Amarelo (66.9). The susceptible cultivars Catuaí Amarelo IAC 62 and Catuaí Vermelho IAC 144 produced 48.1 and 50.5 bags / ha / year, respectively. The cultivar IAC Obatã 1669-20 was delayed, but did not distinguish the IAC Obatã Amarelo. Regarding the characteristics of the seeds, cultivars IAC Obatã 1669-20, IAC Obatã Amarelo had higher percentages of grain type wax and the highest weights of 100 grains. And while for the values of the average blend, the cultivars analyzed showed little variation, being between 17.5 to 18.0. The cultivar IAC Obatã 1669-20 was also the most productive in the experiment without irrigation with 38.8 sac / ha / year, followed by the Catuaí Amarelo IAC 62 (32.0), IAC Obatã Amarelo (28.7) and Catuaí Vermelho IAC144 (21.5). Without irrigation, cultivar Obatã IAC 1669-20 was also vigorous and fruit maturity was the latest among the cultivars. Therefore, the cultivars Obatã IAC 1669-20 and IAC Obatã Amarelo are suitable for ferti-irrigation system which had the highest yield.

**PA 131**

**IAC 125 RN, CULTIVAR OF COFFEA ARABICA RESISTANT  
TO RUST AND TO NEMATODE *MELODOGYNE EXIGUA***

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The aim of this study was to develop a coffee cultivar with short stature and resistant to coffee leaf rust (*Hemileia vastatrix*) and *Meloidogyne exigua*. IAC received in 1971, the hybrid seeds CIPC H361 / 4 (cv. Villa Sarchí x Timor Hybrid, CIPC 832/2), in the F2 generation, which constituted the basis for obtaining the IAC 125 RN. The coffee F2 hybrid H361 / 4 was assigned to IAC 1669, and throughout evaluation of the experiment in Campinas, it was found that the plant F2 IAC 1669-13 stood out among the others, due to its productivity, the size of seeds and resistance to rust and *Meloidogyne exigua*. Selections were made at various locations in segregating generations, and trees resulting from the F6 generation were assigned to IAC 125 RN. In irrigated areas its average yield has been around 60 to 66 bags of coffee / ha / year, and in non-irrigated areas from 33.1 to 59.4 bags / ha / year. The analysis of the types of seeds revealed that this cultivar have large grains with average sieve of 17.4 and 90.2%, 8.0% and 1.8% of grain types of flat, peaberry and elephant beans, respectively. The young leaves are colored green, differentiating it from cv. Tupi IAC 1669-33, which features bronze bud. Its stature is short and the fruits are large, red, and with early maturation. The dimensions of height and its diameter are similar to cv. Tupi IAC 1669-33 and lower than those of cv. Catuá Vermelho IAC 144. Coffee seedlings were tested for resistance to the nematode *M. exigua* race 1. The gall index was 0.5 in this material, with small thickenings, however, without typical galls. In the cv. Catuá Vermelho IAC 144, the gall index was 4.5, with galls very typical. Plants were tested for race 2 of *M. exigua* and also were resistant. These results indicate that this cultivar is highly resistant to *M. exigua*. With regard to reaction to rust, it was found that, under field conditions, so far, the material remains resistant to races prevailing at the places where the cultivar was planted. It is recommended its planting in soils with high fertility in highlands and mainly under irrigation or fertilizers irrigation, since it is demanding in nutrients and water. Due of its multiple resistance to rust and nematode *M. exigua*, the IAC 125 RN cultivar may also be planted in areas infested with *M. exigua*, and it is another great option for the Brazilian coffee growers.

**PA 132**

**PRESERVATION OF SEEDS OF ARABICA AND ROBUSTA COFFEES IN  
THREE STORAGE CONDITIONS**

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Coffee beans, in normal conditions of storage (paper bag, ambient temperature and humidity of 12% to 15% of the seeds), lose their viability very quickly. The two most economically important coffee species, *Coffea arabica* and *C. canephora* generally lose their ability to germinate after three to six months after harvest. For this reason, the normal practice of sowing is done immediately after harvest or at least within six months. Due to this fact, seed producers have difficulties in maintaining its buffer stocks, therefore, nurserymen are required to perform the seeding immediately after harvest, but at this time can not always be the best option. Still, for the production of grafted seedlings with hypocotyls grafting technology for planting in areas infested with nematodes, it would be valuable to keep reserves of seeds of arabica and robusta coffee about a year, since the production of grafted seedlings can occur throughout the year. The objective of this study was to establish an appropriate methodology for the preservation of coffee seeds viable for longer periods. Thus, the IAC have been several studies aiming to inform the best conditions for the storage of arabica and robusta coffee seeds. In this study, seeds of *C. arabica* cv. Mundo Novo IAC 388-6 and *C. canephora* cv. Apoatã IAC 2258 were obtained from coffee cherries, from the crop of 1999. Immediately after harvest, fruits were

pulped mechanically, degummed with natural fermentation for 24 hours and washed in running water. Then seeds were dried in the shade for two moisture levels: high (35-37%) and medium (20-25%). The seeds were placed in two types of packaging: polyethylene plastic bag with single wall thickness of 0.16 mm and woven plastic bag. The seeds were treated with the fungicide Ceiling 600 in the proportion of 1g/kg seeds and after treatment were stored at three different locations. During the storage, tests were performed with germination of the seeds of the cultivars Mundo Novo and Apoatá IAC 2258. It appears that the packaging of polyethylene 0.16 mm thick proved to be efficient in preserving the moisture of seeds throughout the experimental period in all environments, except in the laboratory that showed a small decline. Moreover, the packaging bag twisted allowed to loss of moisture after two months of storage under all tested environments. Seeds kept in a laboratory environment, without control of temperature and relative humidity, showed rapid decrease of germination, from 6 months of storage, especially pronounced in cv. Apoatá IAC 2258, regardless of packaging and initial humidity occurring before that period. The most effective treatment for the preservation of *C. canephora* cv. Apoatá IAC 2258 is that has combined packaging of the seeds with initial moisture content increase of 35% in polyethylene bags in chest refrigerator (10 -16 ° C, 60-90% RH), providing the germination of 76% with 10 months of storage. And *C. arabica* cv. Mundo Novo to better conservation of seeds was in chest refrigerator with 37% initial moisture, kept in plastic bags with thickness of 0.16 mm, which gave a germination of 87% with 12 months of storage. However, when packed in woven bags or polyethylene and stored in cold (10 ° C, 60% RH) the results were similar.

PA 133

### VEGETATIVE PROPAGATION TECHNIQUE OF COFFEA ARABICA PLANTS

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The aim of this study was to develop a technology for vegetative propagation (by cuttings) from plants of *Coffea arabica* and hybrids with high heterosis. After several experiments carried out at Centro de Café 'Alcides Carvalho', belonging to the Instituto Agronômico de Campinas (IAC), the researchers obtained a simple methodology to multiply genotypes of *C. arabica*, suitable to the maintenance of the coffee germplasm bank of the IAC and highly productive hybrids with multiple resistance to diseases, pests and nematodes, excellent quality of the beverage and other agronomic traits. Plants to be propagated must be healthy, in good nutritional condition and in full development. The method for obtaining seedlings for propagation of elite plants of *C. arabica* is to use cuttings taken from orthotropic branches, with three or four pairs of leaves. A pile to be formed of a node with 3-5 cm in length with a pair of leaf reduced to one third of its size, and the base of the pole-shaped bevel cut. Once prepared, the cuttings must be treated by immersion in Derosal systemic fungicide, diluted to 1 ml of the commercial product in 1 liter of water and systemic antibiotic Kasumin (3 ml / l of water) for 5 minutes each product for preventive control of bacteria and fungi. The cuttings should be planted in containers (180 ml tubes, plastic bags for coffee seedlings, etc.) with commercial substrate of pine and expanded vermiculite enriched with macro and micronutrients (Tropstrato Florestal) in a greenhouse under conditions of low light (70 to 80% shade), cool temperature, not exceeding 30 ° C with relative humidity close to saturation. They should stay in this environment for approximately 50 to 60 days when they should be rooted. After this phase, you should gradually reduce watering and increase the brightness to 50%. Seedlings with 4-5 pairs of leaves (4 to 6 months depending on genotype) must undergo acclimation to sun for 15 days after being transplanted to a permanent site. For the formation of elite plants as clones, one must establish the clonal garden. In this case, it is important to note that the planted trees are so dense, irrigated and low-cut height of 1 m to provide the greatest possible number of orthotropic branches and consequently cuttings.

**PA 134**
**INFLUENCE OF DIFFERENT TYPES OF WEED MANAGEMENT  
ON THE QUALITY OF COFFEE (*COFFEA ARABICA L.*)**
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This paper presents aspects related to the effects of different types of weed control on the quality of coffee. It is known that weed can harbor fruits that remains from previous harvests, acting as reservoirs of microorganisms that are harmful to coffee quality, as well as well creating a micro-climate favorable to the development of these micro-organisms, which develops best under high moisture conditions of the soil. Therefore in a classic essay, developed at the Experimental Farm of EPAMIG in the city São Sebastião do Paraíso, Minas Gerais State, with cultivar Paraíso MGH-419-1 to six years old, planted in a spacing of 3,50 x 0,7m , was held during a period that included four consecutive years, the quality of the coffee beans was evaluated in different methods of weed control in the space between lines : mower, harrow, rotary hoe, post-emergence,pre-emergency, hand hoe and no control. The samples were analyzed for coffee beverage according the BSCA (Brazilian Specialty Coffee Association). The results are shown in Table 1. We can observe that, as expected, the results varied from one year to the other; so in the years that conditions are less favorable for the development of microrganisms, the treatments did not differ, as in the agricultural year 2007/08 and 2009/10. However in the other studied years (2008/09 e 2010/11), it could be observed the superiority of the weed control method by herbicide treatment in pre emergency. It was evident that the weed control methods by mowing, grid, rotary hoe and post-emergence herbicide favored the microbiota deleterious to the quality of coffee. The manual weeding, although the similarity of chemical weed control, keeps the ground free of weeds, allowing the spread of microrganisms inoculum in the area, through the contaminated tools. Considering that the execution of a Good Agricultural Program is a important step to obtain a final product of high quality the present results shows that the coffee area must be free of weeds with with a minimum of soil and workers movimentation.

Table 1- Sensorial quality in different methods of weed control, acoording BSCA standards., Agricultural years from 2007/8 to 2010/11- S. Sebastião do Paraíso, MG-Brazil.

Treatments in the space between lines	Total score			
	2008	2009	2010	2011
Mower	84,6a	75,0a	80,7a	78,2 b
Grade harrow	82,3a	78,3ab	82,0a	78,5ab
Rotary hoe	79,6a	76,5ab	83,0a	81,3ab
Herbicide post-emergence	80,6a	78,3ab	81,0a	78,9ab
Herbicide pré-emergency	80,6a	80,3a	82,3a	81,4ab
Capina manual hand hoe	76,0a	75,8ab	82,2a	81,7a
Control	78,0a	77,2ab	79,5a	81,7a

PA 135

## LONG-TERM EVALUATION OF "CONILON" COFFEE YIELD FROM PLANTS PROPAGATED BY CUTTINGS AND SEEDS

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World coffee production in recent years has been around 7.5 to 8 million Ton, mostly in developing countries, supplying the total national demand, providing local employment and promoting rural development, with Brazil as the largest world producer and exporter. In 2011, the brazilian coffee production was 2.61 million Ton, on a cultivated area of 2.3 million ha, with a total of 6,400 millions coffee trees. The objective of this work was to evaluate in a lon-term experiment of 11 years the yield of *C. canephora* cv. Conilon plants implanted both from seed or cuttings, in Vila Valério, Espírito Santo, Brazil, analyzing possible differences among them along that period.

The experiment was performed in randomized complete block design, with two treatments (seedlings originated from seeds and cuttings), and 12 replicates with five plants per plot, implanted by 2 x 1 m, in November 1999. The plant production was analyzed along a 11 year period, from 2001 (17 months) until 2011 (137 months). The production from the plants obtained from cuttings was higher until the 10<sup>th</sup> harvest (although not significantly in the 3<sup>rd</sup>, 5<sup>th</sup> and 6<sup>th</sup>), except for the 7<sup>th</sup> and 9<sup>th</sup>, where plants propagated from seeds presented marginal (not significantly), as observed also in the 11<sup>th</sup> harvest.

Although in the last 7 harvests only two were significantly higher in cutting plants, the accumulated production over a 11 year yields in this plants was higher in ca. 6200 kg ha<sup>-1</sup>, when compared with plants implanted from seed over the same period. That reflects a strong yield advantage in the first years of production of crop implanting using cuttings instead of seeds. Nevertheless, our results showed as well that for longer periods that effect on yield became negligible.

## PA 136

## THE FERTILIZATION IN CULTURE OF COFFEE ROBUSTA IN CÔTE D'IVOIRE: ACQUIRED AND PROSPECTS OF RESEARCH

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The Côte d'Ivoire produced, up to 1990, approximately 300,000 tons of coffee, which ranked 1st in Africa and 3rd in the world of country producers. From 1990 onwards, this production is increased to less than 150 000 tons. The reasons for this decline are among other things, the weaknesses of the world prices, the low level of production of the farms, not recommended technical routes, the aging of the orchards and the conversion of orchards in cocoa, rubber and oil palm. Faced with this threat on national production, several recovery programs have been initiated. These programs advocated the use of improved varieties and techniques for good conduct of nursery and planting and the use of fertilizers. The fertilization has two goals: to meet the nutritional requirements of virgin coconut oil and ensure the balance of mineral and organic soil. In Côte d'Ivoire, after the analysis of soil or soil diagnosis and the dose of doses of fertilizer, the formulas regionalized and the doses have been proposed. The use of mineral fertilizers in the optimal conditions for culture allows for gains in production of the order of 30 to 100 p. c. The rate of adopted of this technology remains small, and view this major constraint, the research is directed toward other sources of fertilizers in coffee farming. It is of the legumes of blankets (*Flemingia*, *Pueraria phasoloides*, etc.), and more recently of the leguminous tree such as *Gliricidia sepium* and *albizia guachapele*. This communication is the point of these different fertilizations in culture of the coffee robusta in Côte d'Ivoire and pulled the prospects resulting research.

## PA 137

## AGRONOMIC PERFORMANCE AND CUP QUALITY OF LEAF RUST RESISTANT ARABICA COFFEE VARIETIES

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In the last years several leaf rust resistant arabica coffee varieties were commercially released in Brazil. Most of these varieties were derived from Híbrido de Timor and from crosses with 'Icatu'. This work evaluated agronomic performance and cup quality of 30 varieties grown under field conditions in the southern region of the Minas Gerais State, an important coffee producing area in Brazil. The following parameters were evaluated: yield, bean size, leaf rust resistance and cup quality. Cup quality was proceeded according to the criteria adopted SCAA, with cumulative scores for sweetness, cleanliness, acidity, mouth feel, taste, after-taste, balance and overall. Several varieties showed high yield during the first four production cycles, yielding more than 1.5 tons of green coffee/ha per year. Leaf rust incidence was observed in IPR 100, IPR 103, Oeiras, two Paraíso progenies and in all varieties of the Catucaí group. No leaf rust was observed in Sabiá Tardio and IBC Palma 2 of the Catimor group and in the other varieties derived from Híbrido de Timor. In the average of two years, all the samples scored above 79 for cup quality, with differentiated special attributes. IPR 104, Catiguá MG 2, Sabiá Tardio e Pau Brasil MG 1 had the highest scores with 89, 86, 85,5 and 85, respectively.

## PA 138

## COFFEE REHABILITATION IN GHANA: RESULTS AND IMPLICATIONS OF A BASELINE SOCIO-ECONOMIC SURVEY

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Coffee used to be one of the most important export crops in Ghana in the late sixties and early seventies with higher producer prices than even cocoa. However, following the period of free fall of global primary commodity prices, coffee prices fell sharply to the lowest level for a century in the period from 2000 to 2004. This fall in world market prices resulting mostly from falling demand severely affected exporting countries like Ghana where domestic demand is virtually non-existent. This collapse in world market prices resulted in the Ghana COCOBOD divesting itself of both production and marketing activities. Recent global trends indicating increasing demand and prices particular over the past decade have encouraged the government of Ghana through the Board to again intervene directly by embarking on a three year coffee rehabilitation project aimed at increasing and sustaining coffee farmers' income especially small holders. The initial 3- year project phase involves helping farmers to coppice old moribund coffee farms, providing improved planting materials for new plantations and also providing technical and financial assistance for farm maintenance. A socio-economic baseline survey was carried out in 2011 with the main objective of studying farmers' current production practices, identifying production and marketing constraints and farmers perceptions about the project generally. Questionnaire was developed, pretested and administered to 250 and 130 project and non-project farmers respectively selected randomly in nine districts in the five project regions in Ghana. The results will also be used as a benchmark for studying future project impact on farmers' income and general standard of living.

The results indicate that most farmers cultivate on the average 3 farms per annum with sizes ranging from 0.5-2 acres, 87% of the farmers used seed as their original planting material with 12% using cuttings. Eighty six percent cultivated coffee on their own or family land, 13% sharecropped while 0.6% either rented or leased their fields. Over 80% of the farmers believe the project if carried out to its logical conclusion will greatly enhance coffee production and particularly land and labour productivity and thus farmers' incomes and general standards of living. Late arrival of project inputs like planting materials and fertilizer were major constraints identified that could identify project impact. Though the project has increased general enthusiasm and interest of coffee farmers, low and unfavorable producer prices is still the single most important constraint militating against coffee cultivation in Ghana. This need to be addressed if the project is to meet its objectives and make the desired impact.

## PA 139

## GLOBAL WARMING IMPACT OF A CUP OF SOLUBLE COFFEE.

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Kraft has been working on sustainability for many years. Sustainability is becoming a growing area of focus within our society and is of interest to our coffee consumers. Kraft has worked both visibly by using Rainforest Alliance coffee beans and refill packaging and 'behind the scenes' improving factory and transport efficiencies. The poster will review our work on life cycle analysis (LCA) of the global warming potential of soluble coffee products. A comparison of different contributions from along the value chain will be made and discussed.

## PA 140

## POTENTIAL PRODUCTIVE OF GENOTYPES OF ROBUSTA COFFEE TO THE SÃO PAULO STATE, BRAZIL.

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Its notorious the growth of the robusta coffee (*Coffea canephora* Pierre ex A. Froehner) in the world. Its participation in the world production passed from 18% in 1965 for 35% in 2010. Brazil is the second producer of robusta in the world, producing an average of 10 millions bags/year. The Espírito Santo state is the most Brazilian producer, with 70-80% of national production. The robusta coffee is not cultivated in São Paulo state. Recently, it had an interest on the part of coffee planters of São Paulo state and by the coffee industry to start the cultivation in São Paulo, what would provide advantages for the coffee grower and for the coffee industry. The Instituto Agronômico de Campinas (IAC) is then intensifying the research for developing cultivars with high productive potential adapted to the climatic conditions São Paulo state. The objective of this work was to select genotypes with high productive potential to be part of the Genetic Improvement Program of the IAC. Two experiments were carried out in Campinas (SP, Brazil), in 2005, in a random block design. The first experiment, called EP 529, was composed of 28 clones, three replicates and four plants per plot. The second experiment, called EP 530, was composed of 30 progenies, four replicates and eight plants per plot. In both experiments, four harvests (2008-2011 were considered). In the experiment EP 529 the results of an analysis of variance showed significant differences in all the harvests and the pooled analysis while in the progenies experiment (EP 530) the significant differences were showed from the third harvest and pooled analysis. The mean productivity in the EP 529, 27.9 bags/ha, was affected by adverse climatic conditions occurred in 2010. The fourth harvest, in 2011, was bigger, 65.0 bags/ha. In the experiment EP 530 the mean productivity was 29.4 bags/ha and the fourth harvest was 62.0 bags/ha. In the experiment EP 529 the best clones were 1, 6, 8, 9, 10, 11, 13, 17 (the most productive, 55.2 bags/ha) 19, 21 and 24; in the experiment EP 530 the best progenies were 3, 4 (the most productive, 41.2 bags/ha) 6, 8, 9, 11, 13, 15, 19, 20, 21, 22, 24, 26, 27, 29 and 30. The continuity of the selection cycles will result in promising future of cultivation of robusta coffee in the São Paulo state.

## PA 141

MULTIVARIATE ASSOCIATIONS AMONG BEAN YIELD AND AGRO-MORPHOLOGICAL TRAITS IN ROBUSTA COFFEE (*COFFEE CANEPHORA PIERRE*)

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Inter-relationships among bean yield and agro-morphological traits is important in developing a strategy for indirect selection for bean yield in Robusta coffee. Multivariate associations among bean yield and several morphological, phenological and bean/fruit traits were determined to identify traits that may be included in a selection index for population and hybrid development. Ten females and four males from the base population at the Cocoa Research Institute of Ghana were crossed in a North Carolina design 2 crossing programme to yield 14 half-sib and 40 full-sib progeny families. The 40 full-sib families were planted in a randomised complete block design with four replications in 2003 and evaluated over a 7-year period. Factor analysis was used to explain dimensions in the data in relation to bean yield in terms of additive genetic effects. The additive genetic values of the 14 genotypes and 13 traits, associated genotypically with bean yield, were projected on the same multivariate plane of the two principal axis of the data. Factor analysis showed that, the relationships among the traits and bean yield could be explained by two factors: general vigour and fertility; and branching habit and fertility. High breeding value for bean yield of six parental genotypes, by their positions on the multivariate plane, could be attributed to their progenies investing assimilates into the production of strong main stems and primary branches, long and erect primary branches, high fruit-set, many fruits at the nodes and few proportions of empty locules; or many primary branches with short internode lengths of the main stem and few proportions of empty locules. These factors could form a basis of a pre-selection index for bean yield in Robusta coffee.

**PA 142****PRODUCTIVITY COFFEA ARABICA L.  
IN NORTHWEST FLUMINENSE REGION**

**RODRIGUES, Weverton\***; **VIEIRA, Henrique\***, **BARBOSA, Dimmy\*\***, **SOUSA FILHO, Gilberto\***, **FREITAS, Sílvio\***

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\*\*Centro Nacional de Pesquisa em Mandioca e Fruticultura – Bahia State – Brazil

The Rio de Janeiro State, which was once the largest producer of coffee, is currently facing difficulties in promoting the expansion of cultivation. In addition to sanitary problems such as *Hemileia vastatrix* Berk et Br and nematodes (*Meloidogyne exigua* Goeldi, 1987) the maintenance of crops old, depleted, as well as the lack of compatible technologies, for example, planting of improved crops, has contributed to the decline of culture in the State. In order to increase productivity breeding programs have sought to launch new coffee cultivars adapted to certain regions, different managements and resistant pests and diseases. However, due to the great diversity of climate between the producing regions, it becomes necessary to study located regarding the adaptation of these new cultivars in order to minimize future risks. In this context, the objective of this study is to evaluate the productivity of 25 genotypes of arabica coffee, wishing in the future, recommend one or more cultivar (s) for the Northwest Fluminense region. The genotypes are being evaluated at a spacing of 2.5 x 0.8 m, and the design used in the experiment in a completely randomized with five replications and eight plants in each replicate, totaling 1000 plants. We evaluated the productivity of 2009, 2010 and 2011 when the plants had 80% cherry fruits. The volume collected was changed to bags benefited ha<sup>-1</sup>, by use of the scale of 480 liters of coffee cherries / processed bag of 60 kg. The variables were submitted to analysis variance and means were grouped by Scott Knott test at 5% probability. In the first harvest in 2009, the genotypes Catucaí amarelo 2 SL, Catiguá MG 02, Sabiá 398, IPR 103/lapar, IPR 100/lapar, Catucaí amarelo 24/137, Catucaí amarelo 20/15, IPR 104/lapar and H 419-10-6-2-5-1, were higher in group averages. At the second harvest in 2010, the genotypes Catiguá MG 02, Acauã, Palma II, IPR 103/lapar, IPR 100/lapar, H 419-10-6-2-12-1, lapar 59 and H 419-10-6-2-5-10-1 were higher in group averages. In the third harvest in 2011, the genotypes Catucaí amarelo 2 SL, Palma II, Sabiá 398, Catucaí amarelo 24/137, Oeiras, Catuaí Vermelho 144, Catucaí amarelo 20/15, H 419-10-6-2-5-10-1, IPR104/lapar , Bourbon amarelo IAC and H 419-10-6-2-5-1 were higher in group averages. The average of the three crops, the genotypes Catucaí amarelo 2 SL, Catiguá MG 02, Palma II, Sabiá 398, IPR 103/lapar, Catucaí amarelo 24/137, Catucaí amarelo 20/15, H 419-10-6-2-5-10-1 and H 419-10-6-2-5-1 were higher in group averages. Some genotypes. Some genotypes showed a more pronounced effect of biannual such as Catucaí amarelo 2 SL , Sabiá 398, Catucaí amarelo 24/137, Oeiras, Catuaí Vermelho 144, Catucaí amarelo 20/15, IPR104/lapar e Bourbon amarelo IAC and H 419-10-6-2-5-1. However, new genotypes such as Catucaí amarelo 2 SL, Catiguá MG 02, Palma II Sabiá 398, IPR 103/lapar, IPR 100/lapar, Catucaí amarelo 24/137, Catucaí amarelo 20/15, H 419-10-6-2-5-10-1 and H 419-10-6-2-5-1 have shown good agronomic performance in conditions in the Northwest Fluminense which may be recommended in the near future for this region.

**PA 143**

**WEED CONTROL UNDER HIGH RAINFALL  
REGIME IN KENYA COFFEE**

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Weeds pose a major challenge in coffee production in Kenya, especially in areas that experience high rainfall and high temperatures. The use of herbicides, while effective, is generally an expensive undertaking and therefore unaffordable to resource poor small holder farmers who produce about 75% of the country's coffee. This study was undertaken to explore various weed control strategies that would be affordable and sustainable. The study was carried out in Kisii and Koru substations of the Coffee Research Foundation in Nyanza province of Kenya. These areas experience rainfall throughout the year. The treatments included weed control methods such as use of herbicides, cultural and use of cover crops. Results showed that cover crops are as effective as the use of herbicides. It was also observed that integration of cultural and chemical control provided effective weed control. A cost benefit analysis of the various treatments will be discussed.

**PA 144**

**INTEGRATING CEDRELA ODORATA TREES INTO  
ROBUSTA COFFEE PRODUCTION IN GHANA - IMPACT  
ON SOIL PROPERTIES AND INITIAL YIELD.**

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The impact of integrating *Cedrela odorata* trees into the cultivation of Robusta coffee was assessed in a field trial established in Ghana in June 2007. Robusta coffee clones, at a density of 1736 plants ha<sup>-1</sup> were interplanted among *Cedrela odorata* trees planted one year earlier, at densities of either 434 plants ha<sup>-1</sup> (Treatment 1); 434 plants ha<sup>-1</sup> to be thinned to 217 plants ha<sup>-1</sup> in the 8<sup>th</sup> year (Treatment 2); 217 plants ha<sup>-1</sup> (Treatment 3); 434 plants ha<sup>-1</sup> to be thinned to 108 plants ha<sup>-1</sup> in the 8<sup>th</sup> year (Treatment 4) or 192 plants ha<sup>-1</sup> (Treatment 5). The standard treatment consisted of Robusta coffee interplanted among *Gliricidia sepium* planted initially at 192 plants ha<sup>-1</sup> but thinned to 48 plants in the 4<sup>th</sup> year (Treatment 6). There were no significant treatment differences in soil pH and organic carbon three years after interplanting the coffee clones among the *C. odorata* and *G. sepium* plants. There was however a general decline in the nitrogen content of the soils in all the treatments during the initial two years after planting the coffee clones but there was a buildup of nitrogen in the soil in the standard treatment (Treatment 6) by the end of the third year. There were no significant treatment differences in the available phosphorus and potassium content of the soils during the initial two years after planting but significantly higher ( $P \leq 0.05$ ) available phosphorus and potassium were recorded after the third year in the soils where *C. odorata* was planted at 192 plants ha<sup>-1</sup> (Treatment 5) and in the control plot (Treatment 6). There were no treatment differences in soil moisture content during the dry season. The initial yield of coffee after the second and third year after planting was significantly higher ( $P \leq 0.05$ ) in Treatments 5 and 6 than in Treatments 1 and 2, giving early indications that *C. odorata* planted at a high density of 434 plants ha<sup>-1</sup> could have adverse effects on the reproductive capacity of Robusta coffee plants.

**PA 145**

**WEED PHYTOSOCIOLOGICAL SURVEY ON CONILON COFFEE  
AND *HEVEA BRASILIENSIS* INTERCROPPING**

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Coffee plant is a perennial crop cultivated in rows and can be productive for more than 20 years. However it is sensitive to weed competition along its developmental stages, so weed control is necessary since the decrease in production can reach 80%. The phytosociological studies compare weed population in a specific period of weed infestation. Programmed repetitions of phytosociological studies can indicate trends in the variation on importance of one or more populations and these variations can be related to the adopted agricultural practices. The floristic evolution of the community occurs according to intensity, regularity and period of system usage. Depending on the intensity, these alterations can affect the management, the control and the competition imposed by this community on the culture. This work aims to survey the weed community in a conilon coffee (*Coffea canephora*) and rubber-tree (*Hevea brasiliensis*) intercropping according to the line distance from rubber-tree to coffee plants.

The evaluation was carried out at the municipality of Jaguaré, located at the North of Espírito Santo, Brazil, and considered the largest region of conilon coffee production in Brazil. It was used complete randomized design with six repetitions. In order to sampling weed population, there were determined six treatments corresponding to the distance from the rubber-tree to the coffee plants rows: 1.5, 4.5, 7.5, 10.5, 13.5 and 16.5 m, respectively treatments 1, 2, 3, 4, 5 and 6. The repetitions were spaced in a distance of 10 m along the culture row. The square frame used in sampling had 0.25 x 0.25 m of inner area and it was thrown from 1.5 m of the line toward coffee inter-row. The species enclosed by each square flame were cut near the ground, packaged in paper bags and took to the laboratory for counting and identification with the use of specialized literature and by comparison with herborized material. After identification, plants were submitted to drying at 70°C for 72 hours. There were measured absolute and relative density, absolute and relative frequency, absolute and relative dominance, and importance value index.

The floristic survey of weeds present in coffee plants and rubber-tree intercropping evidenced the occurrence of 13 species. The treatment number 4 (10.5 m from rubber-tree) presented the highest number of weeds, totaling 10 species. The weed with the highest value of importance was *Commelina benghalensis* followed by *Digitaria insularis* and *Coffea canephora*. Thus, the results indicate that these species are the most problematic in reducing coffee productivity in studied area. Near to rubber-trees there was predominance of dicotyledonous plants. There was difference on the similarity index.

**PA 146**

**EPIDEMIOLOGY OF COFFEE LEAF RUST: INFLUENCE OF SHADE  
ON MICROCLIMATE AND ECOPHYSIOLOGY OF COFFEE**

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The influence of shade trees on coffee productivity depends on many interacting factors such as soil and climatic conditions, coffee and tree species, fertilization regime, shade management, and pest and disease management. Different shade levels provide the basis for identifying the optimum shade conditions which minimize the entire pest complex and maximize the effects of beneficial microflora and fauna acting against it. Field trials to study the epidemiology of the coffee leaf rust under different shade regimes were carried out in medium and low altitude coffee growing zones in Kenya. Sites were selected with trees casting shades over susceptible coffee trees. A trend in PAR, stomatal conductance, leaf temperatures and photosynthetic rates was observed in both low and medium altitudes. Coffee trees under moderate shade and in full sunlight had higher leaf temperature, stomatal conductance values and net photosynthetic rates compared to coffee grown directly under shade. Coffee under shade had higher chlorophyll levels than coffee grown under full sun. The role of temperature, leaf wetness and reduced irradiance in relation to disease incidence will be discussed.

**PA 147**

**AGRONOMIC PERFORMANCE AND CUP QUALITY OF LEAF RUST  
RESISTANT ARABICA COFFEE VARIETIES**

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In the last years several leaf rust resistant arabica coffee varieties were commercially released in Brazil. Most of these varieties were derived from Híbrido de Timor and from crosses with 'Icatu'. This work evaluated agronomic performance and cup quality of 30 varieties grown under field conditions in the southern region of the Minas Gerais State, an important coffee producing area in Brazil. The following parameters were evaluated: yield, bean size, leaf rust resistance and cup quality. Cup quality was proceeded according to the criteria adopted SCAA, with cumulative scores for sweetness, cleanliness, acidity, mouth feel, taste, after-taste, balance and overall. Several varieties showed high yield during the first four production cycles, yielding more than 1.5 tons of green coffee/ha per year. Leaf rust incidence was observed in IPR 100, IPR 103, Oeiras, two Paraíso progenies and in all varieties of the Catucaí group. No leaf rust was observed in Sabiá Tardio and IBC Palma 2 of the Catimor group and in the other varieties derived from Híbrido de Timor. In the average of two years, all the samples scored above 79 for cup quality, with differentiated special attributes. IPR 104, Catiguá MG 2, Sabiá Tardio e Pau Brasil MG 1 had the highest scores with 89, 86, 85,5 and 85, respectively.

## PA 148

COFFEE RUST PROGRESS CURVES IN CLONES OF CONILON (*COFFEA CANEFORA*) IN THE NORTH OF EPÍRITO SANTO STATE, BRAZIL.

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Little is known about the epidemiology of rust on *C. canephora* in the north of the state of Espírito Santo, Brazil. Search the behavior of the rust is on of the prerequisite to building a rational and sustainable disease management program. As a result of climatic fluctuations, changes in cropping systems, increased crop yields and other factors, the behavior of the rust has varied greatly over the years. This fact has led to the indiscriminate use of fungicides which make the control of rust in the field a hard activity. The objective of this study was to understand the behavior of the coffee rust in two clones in the region of the study.

The coffee rust was evaluated in a field that does not use chemicals to diseases control. The rust was monitored in the clone 02 (susceptible to rust), and 143 considered as resistant. Data were obtained from three plots of 25 plants for each clone. The progress to the rust was evaluated monthly, when six leaves were collected from ten plants randomly chosen in each plot. It was counted the number of leaves with rust and determined the percentage of diseased leaves.

With the data of rust incidence was possible to obtain the curve of disease progress for each clone. The disease incidence increased from value close to zero in February, to values close to 100% of diseased incidence in leaves, at September. These data show that the coffee rust continues to grow even after the harvest. Genetic resistance to the rust observed in the clone 143, was able to reduce by 70% the incidence of rust, showing the importance of the use of genetically resistant clones in the management program in the field.

This work was partially supported by Consórcio Pesquisa Café e Fundação de Amparo a Pesquisa do Espírito Santo.

## PA 149

EFFECTIVENESS OF CYANTRANILIPROLE TO CONTROL COFFEE BERRY BORER (*HYPOTHENEMUS HAMPEI*) IN INDONESIA

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Cyantraniliprole is a novel pesticide and second generation ryanodine receptor insecticide. This insecticide is safer than others due to lower toxicity against mammalian and the others. Their effectiveness in controlling main coffee pests, especially against coffee berry borer (CBB, *Hypothenemus hampei*) did not know yet in Indonesia. An experiment has been set up to know the effectiveness of the pesticide against CBB on Arabica coffee in East Java Province, Indonesia, from November 2011 to March 2012. Eight treatments including untreated plot as a control and five levels of cyantraniliprole dosage, as well as single dosage of carbaryl and lamda sinalothrin have been applied in the field condition on each plot composed 20 coffee trees of seven years old. Each treatment has been replicated four times. Applications of insecticide have been conducted two times with interval of one month and started at the condition of coffee seed starting harden. The results revealed that observation of CBB infestation on coffee cherry in the field, cyantraniliprole at the dose of 1750 ml and 2000 ml formulation (10% cyantraniliprole) very effective in controlling both CBB infestation and population until two months after second application. The effectiveness was superior to carbaryl and lamda sinalothrin insecticides. Observation on green coffee and parchment coffee also showed the lower infestation than untreated treatment as well as carbaryl and lamda sinalothrin treatments. Green coffee production on cyantraniliprole was also higher than the others treatments.

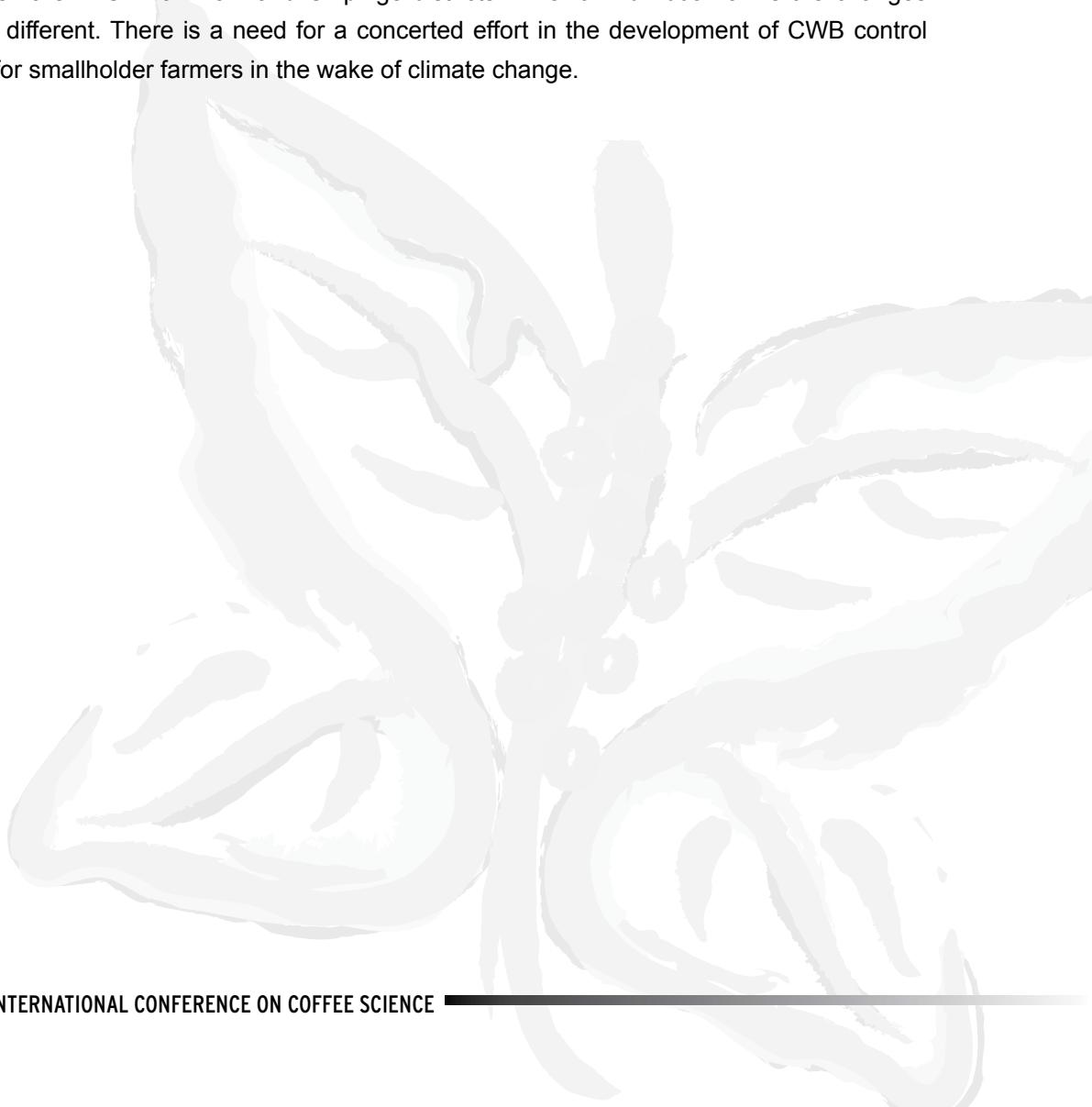
**PA 150**

**THE IMPACT OF CLIMATE CHANGE ON THE OCCURRENCE RISK  
OF COFFEE WHITE STEM BORER (*MONOCHAMUS LEUCONOTUS P.*):  
INDICATIONS FROM EASTERN ZIMBABWE**

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Climate change particularly reduced rainfall reliability and increased temperatures poses great risk of pests and diseases and other stresses to many agricultural crops including coffee. This study sought to understand the distribution of coffee white stem borer (CWB) under current and predicted climate change scenarios using a species distribution modelling approach. Boosted regression trees were used in R for mapping the current and future CWB occurrence risk as well as the change in this risk using presence-absence data on CWB collected in 2003 in the coffee growing areas of Zimbabwe. It was established that the highest current and future risk of CWB from climate change is in parts of Mutasa district. The change in risk of CWB occurrence between 2003 and 2080 ranged between a reduction of 0.23 to an increase of 0.35 across the districts. The greatest changes in risk are in Chimanimani and Chipinge districts while for individual farms the changes in risk from CWB was different. There is a need for a concerted effort in the development of CWB control measures particularly for smallholder farmers in the wake of climate change.



**PA 151**
**THE RELATION BETWEEN COFFEE PHENOLOGY, RAINFALL AND TEMPERATURE IN COFFEE LANDS IN THE SERRA DA MANTIQUEIRA REGION, MINAS GERAIS STATE, BRAZIL**

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The production of specialty coffees is determined by genetic factors, management and environmental features, especially climate. To assess the relation between climate variables and the quality of the beverage, this work analyzed data from meteorological stations in the municipalities of Carmo de Minas, Cambuquira, São Lourenço and Soledade de Minas, Minas Gerais state, Brazil, all of which have been distinguished in international quality coffee contests. The aim of this work was to assess temperature and rainfall data and relate them to the coffee trees' phenological stages. The meteorological data was provided by CEMIG and AGRITEMPO. Table 1 shows the mean, minimum and maximum temperatures and rainfall during the dry (fruit ripening and floral buds) and rainy (vegetative activity and fruit development) seasons. The mean temperatures were between 19 and 21 °C, indicative of conditions favoring a high quality beverage. The minimum temperatures remained below 10 °C, with the exception of Cambuquira, and the highest temperatures reached 29 °C. During the rainy season, accumulated rainfall was between 709 and 1368 mm, a period in which vegetation and fruit development require a good water reserve. The municipality of Carmo de Minas presents the lowest mean rainfall from June to August. The occurrence of a dry season during this phase (fruit ripening and picking) is important for the uniform natural drying of the beans, which also favors a high quality product. All of these data will assist coffee producers in decision making, especially regarding the choice of the best genetic material and management practices, in order to produce specialty coffees.

Table 1: Mean, minimum and maximum annual temperatures (°C) and total season rainfall (mm) in the meteorological stations for the period of years studied.

Municipality - Altitude (m) and Studied Period (years)	Mean temperature (°C)			Rainfall (mm)	
	Mean	Mín.	Max.	Dry season (June to August)	Rainy season (October to February)
Cambuquira - 897 2006- 2010	19,4	12,4	27,9	78,1	1162,9
Carmo de Minas - 948 1999-2008	21,0	7,2	27,2	37,1	839,8
São Lourenço - 953 2000-2011	20,1	7,6	29,0	71,1	1061,7
Soledade de Minas - 1148 2001-2011	19,5	8,0	27,5	45,8	907,2 907,2

**PA 152**

**BRAZILIAN COFFEE FREE-AIR CARBON DIOXIDE ENRICHMENT (FACE) FACILITY: PREDICTING THE IMPACT OF CLIMATE CHANGE**

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The atmospheric CO<sub>2</sub> concentration has been increasing significantly in the last decades, despite the international efforts for the reduction of emissions. The coffee FACE facility (Fig. 1) was established at Embrapa Environment in 25 August 2011, in Jaguariúna (latitude 22°41'S, longitude 47°W, altitude of 570 m a.s.l.), São Paulo State, Brazil, in order to generate field response data in broad-acre coffee to elevated CO<sub>2</sub> air concentration and water supply. Diseases, pests and weeds, as well as plant physiology of two coffee cultivars (Catuaí Vermelho IAC 144 and Obatã IAC 1669-20), multitrophic interactions and soil attributes have been monitored in twelve 10-m-diameter octagonal rings (plots) located within a 7-ha coffee field. Six rings, representing the control treatment, were left under untreated conditions (current atmosphere), whereas other six rings have been treated with pure CO<sub>2</sub> to achieve the concentration of 200 ppm above ambient concentration, supplied by a bulk CO<sub>2</sub> container with the capacity of 20 t.

The system instrumentation is based on wireless sensor network technology. Environmental sensors (infra-red gas analyzers – IRGA - to measure the CO<sub>2</sub> concentration, anemometers, sensors of air and soil temperature and humidity, solar radiation and precipitation) have been adapted to ZigBee modules. Each octagon segment has individual gas valves to compensate the wind direction and a flow control device to compensate wind speed changes.

The FACE facility is part of the project entitled "Impacts of climate change on plant diseases, pests and weeds - Climapest" (<http://www.macroprograma1.cnptia.embrapa.br/climapest>), which has been supported by Embrapa (Brazilian Agricultural Research Corporation).



Figure 1. View of a ring (left) and bulk CO<sub>2</sub> container (right) of the coffee FACE facility.

## PA 153

FIELD STUDY OF THE ATTRACTIVE AND REPELLENT  
POTENTIAL OF SEVERAL VOLATILE ORGANIC COMPOUNDS  
FOR THE COFFEE BERRY BORER

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Chemical analysis of effluvia emitted by coffee berries reveals the existence of numerous volatile organic compounds which attractive properties to the coffee berry borer (CBB) *Hypothenemus hampei* Ferrari are poorly understood. Only ethanol and methanol have a clearly demonstrated attractive potential when mixed; they are widely used as bait in the trapping of this pest. Some volatile organic compounds like methylcyclohexane, ethylbenzene, nonane, octen-3-ol, phenylethanol, trans-2-hexenal and benzaldehyde, induce an electrophysiological reaction and/or a positive olfactometric response in the CBB. On the other hand, camphene and  $\alpha$ -pinene show repellent effect for the CBB when widely released and cis-3-hexenol and 1-hexanol disrupt attraction of the pine shoot beetle. These compounds are tested in field conditions, in order to confirm their attractive or repellent potential, which could be used to improve trapping or allow the development of a push-pull technique.

The seven potentially attractive compounds were tested separately with BROCAP® traps in the field, in association or not with a blend of ethanol and methanol. The compounds tested alone do not attract significantly more than water used as blank; associated with a blend of ethanol and methanol, they do not attract significantly more than ethanol-methanol used as control.

The four compounds selected for their repellent properties were tested in combination with a blend of ethanol and methanol, in the same field experimental conditions. We demonstrate that repellent action of the cis-3-hexenol and 1-hexanol is significantly.

The results of field trials with the supposed attractive volatile organic compounds, disagree with those obtained in laboratory conditions, according to the literature. To overcome that divergence, new studies should take into account different diffusion rate of the compounds. In addition, compounds whose repellent properties are confirmed, offer the possibility to integrate them into pull-push experiments.

## PA 154

## THE SANITATION HARVESTING INCLUDED IN A COFFEE BERRY BORER MANAGEMENT PLAN SHOULD CONCENTRATE ON RESIDUAL FRUITS FROM BRANCHES

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In a coffee plantation with one annual harvest and a marked dry period, how sanitation harvesting should be done to reduce damages caused by the coffee berry borer (CBB) on the harvest?

For two consecutive years, in El Salvador, we measured quantities of attacked and healthy residual fruits in March, as well as attacked and healthy new fruits before the harvest in September, in 12 control plots and 12 plots with sanitation harvesting. In year 1, the sanitation harvesting was done by a team of farm workers without supervision, in year 2, sanitation harvesting was made by a team supervised by a leader previously trained.

In the first case, unsupervised sanitation harvesting does not reduce the number of residual berries significantly in plots. Although the number of residual berries on the branches decreases by 60%, the berries on the ground increase. Moreover, the attack rate of harvest does not decrease significantly. The number of attacked berries in September is linked with the number of attacked berries from branches in March. In the second case, the supervised sanitation harvesting, significantly reduces the number of residual berries on branches (93%) but not on ground. However, attacks by CBB are significantly lower on the new berries before harvest. They fall on average by 11% to 4% of the 12 plots tested.

Residual berry from branches seems to influence new harvest attacks and can be eliminated by supervised sanitary harvest. So, the elimination of residual berries, from branches made through a rigorous sanitation harvesting, is a useful contribution to the control of the CBB

## PA 155

## CHARACTERIZATION OF CULTIVAR ARABICA COFFEE IAC OURO AMARELO

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The cultivar IAC Ouro Amarelo was developed from the recombination occurred at the crossing controlled between selected trees of 'Catuaí Amarelo IAC H2077-2-12-70' and 'Mundo Novo IAC 515-20'. Hybridization (H5010) was held at the IAC, Campinas, SP, Brazil, in 1961. The aim was to give the Catuaí short size, more vigor, trying to get more productive recombination with other favorable agronomic characteristics. In segregating generations, were selected productive plants with fruits yellow, continuing the selections of the descendants of these trees until the F6 generation, which was named 'IAC Ouro Amarelo'. In areas without irrigation its average yield is 30.1 to 43.6 bags of coffee / ha / year and in irrigated areas and from 40.0 to 55.8 bags. Therefore, the trees of the cultivar IAC Ouro Verde are highly productive, but susceptible to rust. The height of plant is short, the internodes are small and the secondary branch is abundant. The root system is well developed, giving appropriate physiological balance with vigorous shoots. The young leaves are colored green and the adult, bright dark green. Usually in Brazil, the two major flowering occur in September and October, and maturing in May and June. The fruits are yellow. The average period, from fertilization to full ripeness of the fruit is approximately 225 days. The average value of the sieve is between 16 and 17 and the percentage of seeds of the flat type is of the order of 95%. The cup quality is excellent and the contribution of coffee Bourbon in their formation is around 62.5%. It is important to cultivate for large coffee growers and for the family farm. Its short height allows the planting of up to 5,000 plants per hectare. It is important in manual or mechanical harvesting and reacts well to any type of pruning. It can be used successfully in irrigated crops or irrigated-fertilized.

**PA 156**

**INFLUENCE OF ROOTSTOCKS TOLERANT TO WATER STRESS  
ON GROWTH, YIELD, AND BEAN QUALITY OF SCION CLONES  
OF COFFEA CANEPHORA IN INDONESIA**

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Coffee cultivation on dry land faces drought condition especially because of recent issue of global warming effect. One effort to solve the problem is by using tolerant clones or varieties as rootstocks. The aim of this research was to study the influence of BP 308, BP 409, and Exelsa as rootstocks, on growth, yield, and bean quality of BP 409, BP 534, BP 936, dan BP 939 clones as scions. The research was conducted in Temanggung district, Central Java Province of Indonesia, using Randomized Complete Block Design 5 replications using 10 plants per replication. The result showed that rootstock influenced stem height and number of branches, leaf relative water content (RWC) during dry season, but not for stem diameter. BP 308 and BP 409 rootstocks supplied water more than Exelsa, as shown by RWC of scion on both rootstocks which were higher (82.0%) than on Exelsa (80.0%). Exelsa rootstock caused scion growth slower, therefore bean yield was lower than on BP 308 and BP 409. Bean yield until 4 years old on both rootstocks were similar. Yield on BP 939/BP 308 dan BP 409/BP 409 (scion/rootstock) tended to be high. Rootstocks did not influence percentage of normal and abnormal beans, and the outturns. Bean outturn was more influenced by clones. Exelsa rootstock improved cup taste in terms of caffeine content, body, astringent, and bitterness characters of scion cherries. It was concluded that greater distance in taxonomy relationship between rootstock and scion, their influence on scion cup test characters was stronger.

**Keywords:** *Coffea canephora, Exelsa, rootstock, scion, relative water content, yield, caffeine, cup test quality*

**PA 157**

**EVOLUTION IN TIME AND SPACE OF COFFEE  
PRODUCTION IN THE REGION OF SÃO SEBASTIÃO DO  
PARAISO, MINAS GERAIS STATE, BRAZIL**

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The region of São Sebastião do Paraíso, in the south of Minas Gerais state, is an important coffee production pole. Its environment features latitude between 800m and 1150m, temperate climate, medium to high water availability, predominantly undulating to soft undulating slope and Oxisols e Ferric Rhodudults. Associated to this environment, medium to high technology production systems can yield high quality beverages.

Geotechnologies such as remote sensing and geographic information systems are used to study the evolution of coffee lands in time. These tools provide more speed and greater accuracy in environmental surveys, which makes them very useful in assessing trends, planning alternative future scenarios and in decision making processes. In this work, geotechnologies were used to map coffee lands in the region of São Sebastião do Paraíso, in the south of Minas Gerais state. The relations in time and space of land use and occupation were assessed.

The assessment of the coffee lands spanned the period between 2000 and 2009. Landsat 7/ETM + and Landsat 5/TM images were used to map land use. SPRING was used to process the images, map the land use and to analyze its evolution.

The results of this work show a 4% increase of the region's coffee lands in the period studied. Between 2000 and 2009, 26% of the coffee fields existing in 2000 were extinct, while 35% remained intact. In 2009 a total of 39% of new coffee fields was observed, reflecting a renewed coffee lands.

The coffee lands migrated to the eastern portion of the region and are characterized by small fields, which indicates also a possible expansion of family farming in the area. Most of the areas that were maintained (intersection) from 2000 to 2009 are constituted by large coffee fields.

Monitoring this coffee region's is important, as this information provides the data necessary for maintaining a competitive and sustainable coffee sector. Remote sensing satellite images, digital processing techniques and SIG provide valuable data and should be used to monitor and to assess the dynamics in time and space of coffee lands.

**PA 158**

### **RELATIONSHIP BETWEEN COFFEE AND ENVIRONMENTAL PRESERVATION IN THE SERRA DA MANTIQUEIRA, MINAS GERAIS, BRAZIL**

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The human activities have caused loss and fragmentation of natural habitats, and seriously threatened the conservation of biodiversity. Geographic Information Systems and Remote Sensing enables us to analyze the physical structure of different landscapes, and helps in deciding strategies for conservation. In this study, geotechnologies were used to carry out the environmental characterization of the Serra da Mantiqueira region of Minas Gerais, and create a geographic database. The physiographic structure of the study area was characterized aiming at analyzing and crossing biotic and abiotic variables that act on the local landscape configuration. The results showed the study area is rich in natural resources, with high drainage density, high variation in height and geomorphological features quite different. The human impacts changed the local landscape structure over time, and limited the ecosystems ability to perform their ecological functions. Pasture was the human activity of greater negative environmental impact, due to the inadequate management of some areas. The change of land-uses for agroforestry systems, based on sustainable development, can represent an alternative to the compatibility of agricultural production and conservation of local natural resources.

**PA 159**

### **INTEGRATED COMMUNICATION AND INFORMATION FLOW IN THE INTEGRATION BETWEEN UNIVERSITY-INDUSTRY-GOVERNMENT (TRIPLE HELIX) IN THE COFFEE AGROSYSTEM**

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This is a time of growing demands for innovations which can bring solutions for bottlenecks as well as competitive advantages to the different productive chain links. In this sense, this work proposes a new view on the role of communication and coordination model of the actors in an interorganizational innovation network. Used as an object of analysis the Polo Excellence Coffee (PEC), as representative of the relationship between university, business and government (UBG), highlighted by the Triple Helix Theory. In this interactive environment, each helix has experienced new roles and living with the challenges of communicating and interacting with actors of different segments. For the efficiency of a sectoral innovation system, in this study confirms the importance of an articulating central agent, to support communication and coordination the space for conversation between to all stakeholders. As a result, it is suggested the creation of an information architecture that promotes parity

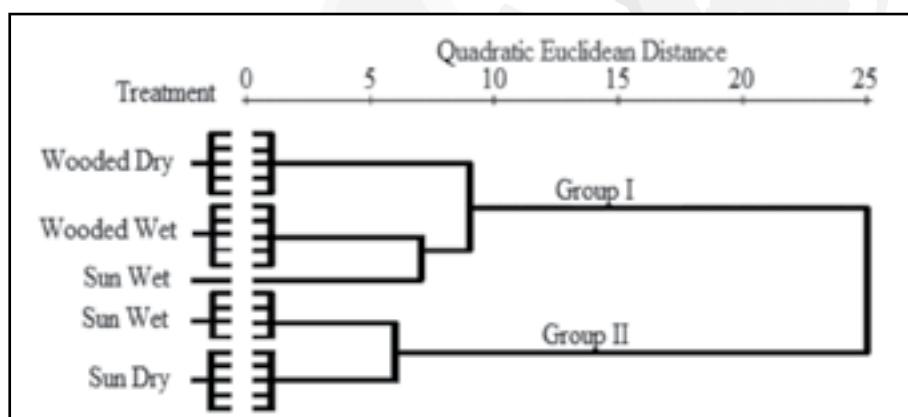
between the information needs of the enterprises and the knowledge generated by research centers and universities, and the contribution of the government incentive to their interrelations. However, this complexity requires the establishment of an open and frequent communication with synergy of language, ease of processing and accessibility to all stakeholders. In this sense, the paper contributes, in theory, to reflect on the importance of articulating central agents to the relationship between U-B-G that, conceptually, can be treated as hybrid organizations. To validate this interaction model; It was used the in-depth interviews with nine actors linked to the PEC and proceeded the analysis of categorical content. The empirical results show that the combination of U-B-G is encouraged, especially through information flows. Thus, the theoretical contribution of labor, which is supported by the empirical results of the study, is located in defense of the joint function of the Triple Helix increases in capability if it is continuously incorporated into the vision of integrated communications and hybrid organizations, because these concepts just keep contributions to thinking at systematicity and the opening of channels between U-B-G, aiming at the success of the coffee activity.

**PA 160**
**HIERARCHICAL CLUSTER ANALYSIS IN SHADED AND UNSHADED COFFEE, WITH POST-HARVEST MANAGEMENT**

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**Objective:** Assessing the quality of Arabica coffee, Catui variety, grown in full sun and under trees, wet processing and dry in Vitória da Conquista - Bahia, Brazil. The experimental design was randomized blocks, in a factorial 2 x 2 (fruits from two forms of cultivation - full sun and wooded with *Grevillea robusta*, A.Cunn and two forms of processing – dry and wet – pulped), consisted of five blocks and 20 plots (10L fruit) in accordance with the treatment. Was evaluated: 17 sieve above, 13-16 sieve, 'moca', bored, defects, total titratable acidity, soluble solids, reducing sugars, non-reducing sugars, total sugars, caffeine, total chlorogenic acid, phenolic compounds total, and activity of polyphenol oxidase. Due to the different factors that influence the quality of coffee, we performed a hierarchical cluster analysis, order to develop a characterization study of the variables that indicate the quality of coffee by using SPSS 17.0 (Statistical Package for Social Sciences). The AAH (Figure 1) is a cluster analysis technique based partition of a heterogeneous population in several homogeneous groups. In the group there is no pre-defined classes, the elements are grouped according to similarity.



**Figure1:** Dendrogram of the similarity analysis between variables, Arabica coffee from the shaded system and full sun, and post-harvest processing, dry and wet.

The dendrogram is a simplified two-dimensional projection of an n-dimensional relationship. The analysis of the figure shows the formation of the two groups studied coffee. The effect of the conduct of the plantation to clearly interfere in the selection of coffees. The coffee wooded independent of post-harvest handling and coffee conducted to full sun when processed by wet, showed greater similarity, differing from the second group, consisting of coffee conducted to full sun. The quadratic euclidean distance, determines the similarities of the treatment the greater this distance, the lower the similarity of the coffees analyzed.

**Conclusion:** The conduct of the plantation interfere in the selection of quality coffees.

**PA 161****WATER EXCESS IN COFFEE SEEDLINGS  
(*Coffea arabica* L.): EFFECTS ON GROWTH**

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The excess of water in agriculture, not only affects yield, but also makes difficult the control of diseases and weeds. It also increases the lixiviation of nutrients, and the costs of cultural practices. Not to mention that it may result in environmental problems such as contamination of the water layer, soil salinity and erosion. Among the studies related to coffee water relations, none deal specifically with the excess of water in the plant's development. Most of it is concentrated on the use of irrigation as a solution to the problems related to water deficit. Even though most authors do not go into details why coffee yield is often decreased in face of water excess, in the literature, it can be found many papers explaining why most of the plant species do not tolerate the excess of water. During flooding, oxygen diffusion becomes very low, causing a state of hypoxia (deficiency of O<sub>2</sub>), which can easily develop into anoxia (lack of O<sub>2</sub>). In such environments, an immediate drop in the respiration of roots occurs, inhibiting the metabolic activity of the roots, and consequently the production of ATP, which restricts the energy supply for root growth, causing a reduction in the overall development of the plant. Due to the low availability of oxygen, the fermentative pathway is activated to produce acetaldehyde, ethanol and/or lactate, which provide a minimal quantity of energy. In some cases, also occurs the formation of free radicals that may eventually lead the plants to death. Therefore, the objective of the present study was to evaluate the influence of 20 weeks of soil-waterlogging on the growth and biomass accumulation in plants of Mundo Novo IAC 379-19 and Catuai Vermelho IAC cultivars. For that, plants, with eight pairs of leaves, were subjected to three different conditions of water availability in the substrate: (i) control (well watered), (ii) substrate-waterlogging (seedlings were kept in a plastic recipient with water to the setup level above two thirds of the polyethylene bags), (iii) intermittent substrate-waterlogging (seedlings were kept for three days under continuous waterlogging and then four days under field capacity, during the whole experiment). Many traits related to growth were evaluated during 20 weeks. The combined analysis revealed that, based on the number and quality of the affected variables, the Catuai cultivar, showed after two months of stress, higher susceptibility to flooding. Among the variables affected, the number, area and dry matter of the leaf should be highlighted, since it were reduced by near 25, 29 and 30%, when seedlings of such cultivar were kept under continuous flooding conditions. This sensitivity to flooding, however, was comparable to the Mundo Novo susceptibility at five months of water excess, irrespectively if it were continuous or intermittent. Data related to dry matter of the roots compared to the data of roots smaller than 3 mm indicate that radicles were the first to die, with a substantial reduction after 2 months of stress. On the other hand the dry matter of the roots only presented reductions in weight after 5 months of induction of the continuous and intermittent flooding. Both cultivars presented significant reductions in all roots variable studied.

**PA 162**

**CONTROL OF COFFEE BERRY BORER  
(*HYPOTHENEMUS HAMPEI*) AND INCREASE OF  
COFFEE YIELDS USING SURROUND WP (KAOLIN)**

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Surround WP was sprayed on coffee to measure its ability to control coffee berry borer (*Hypothenemus hampei*) and increase yields. Two coffee farms in Kona, Hawaii, were selected as cooperators. Farm 1 had two treatments: control and Surround WP. Farm 2 had four treatments: control, Surround WP, *Beauveria bassiana* (Bb), and Bb + Surround WP. The Surround WP showed 59% (Farm 1) and 79% (Farm 2) control of coffee berry borer compared to the control. The Bb + Surround WP showed the best control. Bb by itself was not significantly different than the control. Surround WP did not significantly increase yields on Farm 1. On Farm 2, the Surround WP treatment had significantly greater yield than the Bb treatment. The other treatments had statistically similar yields. Surround WP seems to be a promising tool to manage the coffee berry borer.



**PA 163**
**CONSUMPTION AND BIOPROTECTION OF COFFEE COMPONENTS IN THE PRESENCE OF MYCOTOXINS ON WISTAR RATS**

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Coffee is nothing less than the second most consumed beverage in the world; its taste and attractive aroma justify its acceptance. Several studies have been conducted to determine their effects on human health. Confronted with evidence found in literature, this study sought to confront, by "in vivo" testing, the bioprotective action of the most important chemical compounds in coffee (i.e. chlorogenic acids) and two known mycotoxins (ochratoxin A and aflatoxin B1). The experiment was composed of four biological tests. Young Wistar male rats were used in this study, being kept in a controlled environment with 12 hours photoperiod and ambient temperature of about 25 °C during the whole experiment. All mice were maintained in individual metabolic cages with access to controlled food (15g/day) and "ad libitum" water. During each test, that last for about four weeks, each animal received 50ng of toxin/day on 3g of powdered milk which was shaped into a sphere by adding 1.5 ml of distilled water. Animals from the negative toxin groups received the same treatment, without however the addition of the mycotoxins. Recorded data (weight gain in grms) were compared by Scott Knott and Student t tests at 5% of probability. The bioprotective action of coffee towards the mycotoxins, especially by chlorogenic acids, was clearly noted, since in the groups that received the addition of chlorogenic acids, a significant improvement in weight gain was noted (Tables 1 and 2).

Table 1 Average weight gain (g) of animals subjected to different concentrations of chlorogenic acids in the absence or presence of AFB1: Assay I

Levels of <sup>1</sup>	Aflatoxin B1 <sup>2</sup>					
	Absence		Presence			
Chlorogenic acids	a	B	184,875 (± 5,083)	b	A	
0	205,375 (± 5,083)	a	B	184,875 (± 5,083)	b	A
1	197,625 (± 5,083)	a	B	178,500 (± 5,083)	b	A
2	197,750 (± 5,083)	a	A	222,875 (± 5,083)	c	B
3	209,500 (± 5,083)	a	B	156,875 (± 5,083)	a	A

CV = 5,24

Means followed by same letter in the column and capital on the line do not differ by the Scott Knott test (1) and Student's t (2) the probability level was 5%

Table 2 Average weight gain (g) of animals subjected to different concentrations of chlorogenic acids in the absence or presence of OTA: Assay II

Levels of <sup>1</sup>	Ochratoxin A <sup>2</sup>					
	Absence		Presence			
Chlorogenic acids	a	A	130,000 (± 5,808)	a	A	
0	120,875 (± 5,808)	a	A	130,000 (± 5,808)	a	A
1	136,625 (± 5,808)	a	A	126,250 (± 5,808)	a	A
2	124,000 (± 5,808)	a	A	126,750 (± 5,808)	a	A
3	131,125 (± 5,808)	a	A	124,000 (± 5,808)	a	A

CV = 9,11

Means followed by same letter in the column and capital on the line do not differ by the Scott Knott test (1) and Student's t (2) the probability level was 5%

It was not found whatsoever, any differences on biochemical and histopathological exams.

**Keywords:** Chlorogenic acids. coffee. Aflatoxin B1. Ochratoxin A.

PA 164

PRODUCTIVITY AND ROOT SYSTEM OF COFFEE CULTIVATED  
UNDER DIFFERENT POPULATION ARRANGEMENTS, WITH  
AND WITHOUT IRRIGATION.**SILVEIRA, Jane M.C.\*, SAKAI, Emilio\*\*, BARBOSA, Eduardo, A.A.\*\*\***

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The use of irrigation is an increasingly common practice at the cultivation of coffee, due to improvements in production environment, resulting in productivity gains. In order to obtain good yields with quality and a more rationalization in water and nutrient use, it is necessary to know the distribution of the roots system for a more efficient application of irrigation depth. The lack of information regarding the root distribution of irrigated coffee trees brings about the use of information from rainfed system when designing a project. The purpose of this research was to evaluate the coffee production during two cultivation cycles and the root system of *Coffea arabica* (cv. Catuai) cultivated under different population arrangements, with and without irrigation interposed with the fertigation by drip irrigation. The experiment with *Coffea arabica* L. cv Catuaí was carried out in Mococa, São Paulo, Brazil. The soil of experimental area was a medium texture Ultisol. The experimental design was a 6 x 2 factorial scheme in randomized blocks, with four replications. The six densities of plantation were E1 (1.60 x 0.50); E2 (1.60 x 0.75); E3 (1.60 x 1.00); E4 (3.20 x 0.50); E5 (3.20 x 0.75) and E6 (3.20 x 1.00), which were divided according to water availability (irrigated or non-irrigated condition). The yield of processed coffee in 2009/2010 and 2010/2011 cultivation cycles was assessed. After the harvest of the second cycle, with the aid of a root auger, samples of roots were collected in layers of 0.1 m up to 1.0 m depth, at points 0, 0.4 and 0.8 m from orthotropic branch in E1, E2 and E3 treatments and 0, 0.4, 0.8, 1.2 and 1.6 m in E4, E5 and E6 treatments. Data were submitted to analysis of variance and averages compared by Tukey test at 5% of probability. In the 2009/2010 cycle, E1 treatment showed higher yield of processed coffee (4631 kg ha<sup>-1</sup>), when compared with E4, E5 and E6. In the 2010/2011 cycle, E2 and E3 treatments had higher production of processed coffee, 1051 and 1515 kg ha<sup>-1</sup> respectively, which contrasted with coffee cultivated in E4, E5 and E6 population arrangements. The irrigated coffee in the two cycles showed increased production of processed coffee, with average yield of 4162 kg ha<sup>-1</sup> in the 2009/2010 cycle and 1702 kg ha<sup>-1</sup> in the 2010/2011 cycle; for the coffee tree cultivated in rainfed condition, the average yield was 2985 kg ha<sup>-1</sup> in the 2009/2010 cycle and 134 kg ha<sup>-1</sup> in the 2010/2011 cycle. The irrigated treatments showed higher concentration of roots at the point of the orthotropic branch, while the coffee tree cultivated in rainfed condition presented lateral distribution of roots in relation to the orthotropic branch. Irrigated cultivation presented higher concentration of roots when compared to rainfed one in the evaluated area, except for E2 treatment. There was no influence of irrigation on the deepening of root system. For treatments in which spacing of 1.6 m between rows was used, 90% of roots were concentrated in the layer of 0 to 0.5 m, while for those in which spacing of 3.2 m between rows was used, 90% of roots were concentrated in the soil layer of 0 to 0.6 m, except for E6 treatment. Additionally, E4 and E5 treatments presented 80% of the roots in the layer of 0 to 0.5 m.

## PA 165

FROST TOLERANCE OF *Coffea canephora* CLONES IN THE NORTHWEST OF THE STATE OF PARANA, BRASIL**SANTORO, Patricia Helena\*, ANDROCIOLI FILHO, Armando\*, FANTIN, Denilson, PISSINATI, Aline\***

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The optimum annual mean temperature ranges from 22 to 26°C for the cultivation of *Coffea canephora* and it is less adaptable to lower temperatures than *C. arabica*. The occurrence of periodic frosts has been one of the main constraints to the economic exploitation of coffee in the regions between 20° and 24°S latitudes, causing oscillations and risks of production losses. With initial objective of evaluating the adaptability of *C. canephora* in the Northwest of Paraná, 29 clones selected by Incaper (Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural) in the State of Espírito Santo, Brasil, were installed in the city of Iporã, PR, Brasil (23° 59' S latitude and 53° 45'W longitude). The planting of coffee seedlings was carried out in the second half of February 2011. The space was 3 m between rows by 1 m in the row and under drip irrigation. During the winter of 2011, approximately 120 days after planting time, occurred in this region three frosts characterized by temperatures below 3°C under shelter conditions that affected the experimental area. For this reason, were carried out evaluations for tolerance of the *C. canephora* clones in relation to damage caused by frosts. The evaluations were performed 90 days after the occurrence of the first frost and 50 days after the last one, which allowed confirming the death and verifying the ability of regrowth of the clones. Coffee plants were classified as to the level of damage, in three groups: lived plants with green leaves (plants with retained undamaged leaves), lived plants with buds (plants that lost all the leaves, but had living buds and start sprouting) and dead plants (unviable plants, unable to resprout). The experimental design was randomized blocks with four replications and each plot consisting of 15 plants. The data were submitted to ANOVA and the means were compared by Tukey test ( $p < 0.05$ ). The coffee clones less damaged were: 3V and 4V (Incaper 8142 – Conilon Victoria), and 501 and 502 (Ipiranga), which showed between 60 and 81% of lived plants with retention of undamaged leaves, and not differing among them. The greater capacity for regrowth was observed for clones 3V and 6V (Incaper 8142 – Conilon Victoria), 19 (Robustão Capixaba) and 501, with 18-60% of plants showing alive buds and early sprouting. Among the 29 clones, 23 showed greater susceptibility, with mortality ranging from 55 to 100% and not significantly different. The identification of clones with increased tolerance to frosts is important for coffee regions where there is the possibility of occurrence of this weather event, like the State of Paraná where severe frosts occur every five or six years.

## PA 166

## PERFORMANCE OF CLONAL SELECTIONS OF ARABICA TYPICA COFFEE RESISTANT TO LEAF COFFEE MINER, IN CAMPINAS, SP.

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The performance of four Arabica clones resistant to *Leucoptera coffeeella* has been estimated from studies of populational fluctuation based on monthly assessment in marked branches. After three years of field evaluations, the four clones are revealing resistant to the insect. In addition, laboratory tests were carried out confirming the observed results. Beside the assessments related to resistance to *L. coffeeella*, the clones have also been evaluated regarding resistance to coffee leaf-rust (*Hemileia vastatrix*) and halo blight (*Pseudomonas garcae*). The promising results obtained in the field should be confirmed in laboratory tests. Other information related to fruit production, plant fertility, incidence of voids, average plant height, earliness of ripening and fruit color are also discussed in this work.

**PA 167**

**GROWTH OF COFFEE SEEDLINGS SUBMITTED  
THE APPLICATION OF CITRIC ACID**

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JUNKER, Lariane C.\*\*, FRANÇA, André C.\*\*, SILVA, Enílson B. \*\*, CARVALHO, Gladyston R.\*\*\***

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The objective was to evaluate the quality, growth, and nutritional content of seedlings of Catuaí Vermelho (IAC-99) coffee, submitted the application of citric acid and phosphorus concentrations in the substrate. It was used the factorial scheme (4x4), being the first factor concerning the application of citric acid to the substrate (0, 1, 2 and 4 kg ha<sup>-1</sup>), and the second concerning the doses of phosphorus (0, 450, 900 and 1800 g P<sub>2</sub>O<sub>5</sub> m<sup>-3</sup>) in the substrate. The experimental design was a randomized complete block with five replicates. The seeds had been germinated in bags on common substrate, respecting the treatments with applications of phosphorus. On the 70<sup>th</sup> day after sowing (DAS), when the seedlings had four to five pair of leaves, a solution of citric acid was applied. The evaluation have been held at 180 DAS when the seedlings had four to five leaf pairs. It was measured height, stem diameter, leaf number and leaf area of plants. In the same period there have been collected all the leaves of the seedlings to determine the levels of macro and micronutrients. There have been measured at the dry leaves, stems and roots, and root length density and Dickson quality index. The dose of 1 kg ha<sup>-1</sup> of citric acid was the one that most positively influenced the growth and quality of seedlings on the standard dose of phosphorus (900 g P<sub>2</sub>O<sub>5</sub> m<sup>-3</sup>) to form the substrate. There was a reduction in the leaf content levels of P and Zn when applied citric acid in the substrate with standard phosphorus. However, it was detected an increase in Ca, N, P, S, Cu, Fe and Zn in doses from 1.6 to 4.0 kg ha<sup>-1</sup>from seedlings in the citric acid in phosphorus-free substrate.

**PA 168**

**GROWTH AND NUTRITIONAL STATUS OF COFFEE SUBMITTED  
THE APPLICATION OF CITRIC ACID WITH AND WITHOUT  
PHOSPHORUS IN THE PLANT**

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The objective was to evaluate the initial development and nutritional status of coffee seedlings (*Coffea arabica*) submitted the application of citric acid with and without the use of phosphorus in the plant. The factorial (2 x 4) had been used, being the first factor to evaluate the normal dosage and the absence of phosphorus in the pit, and the other the effect of 0.0, 1.0, 2.0 and 4.0 kg ha<sup>-1</sup> of citric acid on the furrow. The experimental design was a randomized complete block with four replications. Data have been collected from the plants at the 75<sup>th</sup> and 180<sup>th</sup> days after the application of citric acid (DAA). There have been measured height, stem diameter, number of leaves, root length and volume and leaf area of plants. They were divided into leaves, stems and roots, weighed and placed to dry at 60°C until they reach constant weight for determination of dry matter of plants. At 75<sup>th</sup> and 180<sup>th</sup> DAA leaves (third pair) of primary branches were collected, to evaluate the nutritional content of the plant. The dose from 1.0 to 2.0 kg ha<sup>-1</sup> of citric acid was the ones who most influencing growth when not used phosphorus in planting. The application when using phosphorus causes a decrease in the growth and Ca, K and Fe of plants at 75<sup>th</sup> DAA. Zn levels at 75<sup>th</sup> DAA, and Cu at 180<sup>th</sup> DAA increase regardless of P fertilization at planting.

## PA 169

## APPLICATION OF CITRIC ACID IN COFFEE PLANTS IN ALTO JEQUITINHONHA (MG): PRODUCTION AND CRITICAL RANGES OF NUTRIENTS IN THE LEAVES

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The objective was to evaluate the influence of citric acid application on the soil, productivity, foliar nutrient content and to estimate their critical ranges in three crop years (2009/2010/2011) in the city of Diamantina (MG). Using the Catuaí Vermelho IAC-44 (*Coffea arabica* L.) seven years old, with one plant per hole (3.8 x 0.7 m). They were applied in a single dose under side of the plant, four doses of citric acid (0, 1, 2 and 4 kg ha<sup>-1</sup>) in a dystrophic Red-Yellow Plinthic Alfisol (DBP) (*Argissolo Vermelho Amarelo distrófico plintílico (PAd)*). The experimental design was randomized blocks with two replications of treatments in each block with four blocks. Were evaluated the productivity of coffee beans, foliar concentrations of nutrients (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn) and estimated the critical ranges of the leaves in function of doses of citric acid to an average of three harvests (2009/2010/2011). Coffee production was positively affected when added 1.2 and 2.4 kg ha<sup>-1</sup> of citric acid for 90% of the maximum and the maximum production, with increases of 14.5 and 27.2% in productivity. The application of the product in the soil increased the uptake rate of P, K, Ca, Mg, Cu, Fe, Mn and Zn, reflecting higher foliar these nutrients. The critical ranges of nutrients in the leaves as a function of the applied doses of citric acid, these being: 0.14 to 0.15 dag kg<sup>-1</sup> for P, 3.12 to 3.21 dag kg<sup>-1</sup> for K, 1.14 -1.18 dag kg<sup>-1</sup> for Ca, 0.16 to 0.18 dag kg<sup>-1</sup> for Mg, 0.27 to 0.23 dag kg<sup>-1</sup> for S, 61.8 to 57.4 mg kg<sup>-1</sup>to B, from 48.1 to 55.8 mg kg<sup>-1</sup>for Cu, 86.3 to 91.6 mg kg<sup>-1</sup>for Fe, 87.8 to 93.6 mg kg<sup>-1</sup>for Mn, 49.1 to 60 , 0 mg kg<sup>-1</sup>for Zn.

## PA 170

COFFEE LEAF MINER - *Leucoptera coffeella* (Guérin-Mèneville, 1842) (Lepidoptera: Lyonetiidae) FLOATING POPULATION IN SOUTHERN STATE OF MINAS GERAIS - BRAZIL

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Currently Brazil stands as the world largest coffee producer, and more than half of this production is concentrated in Minas Gerais state (Conab, 2012). Among the factors affecting coffee production, there are pests especially as coffee leaf-miner [*Leucoptera coffeella* (Guérin-Mèneville, 1842) (Lepidoptera: Lyonetiidae)] which every year causes major damage affecting crop development and production. The monitoring of this pest is an important tool, because through correlation with the climatic data of the region, may in future define management strategies in order to prevent the coffee leaf miner reaches levels that cause economic losses, given that the population of this insect is greatly influenced by climatic conditions. The experiment was conducted in the EPAMIG Experimental Station at São Sebastião do Paraíso, in the Southern of Minas Gerais. To perform the monitoring the coffee leaf miner one plot of 1,000 plants was demarcated, in area with Catigua MG1, a coffee cultivar, planted at 3.5 x 0.70m. This area did not receive any insecticide treatment, and only cultural practices typically undertaken at appropriate times. Ten representative plants in that area were chosen at random. In

each plant, five leaves at the third pair from each branch were collected separately at the upper, middle and the bottom part of the plant and their average calculated, totaling 20 leaves by third pair and 60 leaves /plant. Samples were collected each 15 days and registered in a spreadsheet noting the number of leaves with leaf miner injuries. The mean of 10 plants was calculate and the mean resulted of the two evaluations performed within each month. By having the data in the levels of infestation and the monthly climatic data collected at the Meteorological Station of EPAMIG, graphs were made showing the leaf miner fluctuation in the last 10 years in the period 2002 to 2011. It was found for that the infestation of the coffee leaf miner begins to increase from May and extends to a peak usually in August, from this month the population decreases rapidly due to the rains onset in the region. The monitoring is extremely important to follow the insect population growth, seen that this increase is strongly influenced by climatic factors.

PA 171

### FLOATING POPULATION OF COFFEE BERRY BORER - *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera - Scolytidae) IN SOUTHERN STATE OF MINAS GERAIS - BRAZIL

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The coffee cultivation is an important activity in the southern of Minas, where concentrates a quarter of national production. However, every year the production and quality are affected by the attack the coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867), due to the direct and indirect damage they cause. Climatic conditions present in the coffee region influence the development of this insect especially during the intercrop since their survival during this period occurs in the fruit remaining on the plant. The objective of this study was to monitor the coffee borer fluctuation for an eight years period according to climatic conditions in the region. The experiment was conducted at EPAMIG Experimental Station, in São Sebastião do Paraíso southern state of Minas Gerais - Brazil. To accomplish the monitoring a plot of 1500 coffee plants was properly demarcated in an area planted with coffee cultivar MG1474 Acaíá at 3.20 x 0.70 m row spacing. Fifty representative plants were randomly selected. This area did not receive any insecticide control, but only the routine cultural practices performed normally. Forty fruits per plant were monthly collected, 20 fruits on each side of the plant, ranging from the middle third to the lower third totalizing 2000 fruits. After harvesting, the damaged fruits were separated, and counted. This procedure was performed monthly starting from three months after the first blooming, starting in December and ending at the harvesting. The first sampling was done at the top plants, where the larger green fruits are found followed by other samples as explained above. The fluctuation and climate data, of the EPAMIG meteorological Station from 2004 to 2011 were compared in a chart. It was observed that coffee berry borer infestation starts at fruit formation period, in December and progresses to the crop, usually in August. During this period there is attack intensity variation, possibly due to the life cycle and climatic conditions in the region. The coffee borer infestation is positively correlated to precipitation. This factor can be limiting to their survival and reproduction, since the lack of moisture undertakes their development. The coffee berry borer monitoring is an important tool because it allows determining the onset and evolution of the attack and thus applying control measures at the right time, avoiding unnecessary application of pesticides and environmental contamination. Therefore, it was evident that one can predict the coffee berry borer attack and anticipate the control measures. In addition, preventive measures may be adopted with harvesting well done and harvest repasses in order to avoid the adult of this insect during the intercrop. The cultivars early planting can also help reduce the damage caused by this pest with the early harvest.

## PA 172

ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS OF COFFEE  
CULTIVARS RESISTANT TO DISEASES AND PESTS IN THE  
DEVELOPMENT OF BRAZILIAN COFFEE REGIONS**BLISKA, Flávia\***; **VEGRO, Celso\*\***; **FRONZAGLIA, Thomaz\*\*\***; **TURCO, Patrícia\*\*\*\***; **FAZUOLI, Luiz\***

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Immunity or tolerance to pests and diseases provides less use of chemicals and therefore significant savings for the producers, and significant reduction of risks related to environmental pollution and health of farmers and consumers. Consequently, the innovative characteristics of cultivars with resistance to diseases and pests are consistent with the growth of world demand for products made by technologies that minimize residues, waste, unnecessary costs and result in significant and positive impacts on health of workers, farmers and consumers, contributing to sustainable rural development. This study examines the environmental and social-economic impacts of the adoption of cultivars resistant to pests and diseases in developing sustainable of coffee regions, based on the assessment of resistant cultivars developed at the Instituto Agronômico - IAC (Agronomic Institute): Tupi IAC 1669-33, Tupi RN IAC 1669-13, Obatã IAC 1669-20 e Apoatã IAC 2258 (rootstock). These cultivars have high yield potential and good agronomic and technological characteristics, and stand out for use in conventional or organic crops, family or business, in areas with soil and climatic conditions favorable to the spread of specific diseases and pests. Moreover, the cultivar Tupi RN IAC 1669-13 presents multiple resistances, which provides additional advantages compared to other resistant cultivars. Initial results indicate that, among the cultivars analyzed, the cv. Tupi RN has show very promising results, particularly in regions with infestation of the nematode *Meloidogyne exigua* and can become strategic for the expansion or maintenance of coffee extensive area of Minas Gerais State, known as Cerrado. Among IAC cultivars resistant to pests and diseases, the cv. Apoatã IAC 2258, which is used as rootstock, has resulted in the largest regional environmental and socioeconomic impacts.

Keywords: Rural development; Technological innovations; Resistant coffee cultivars.

## PA 173

PHYSICS AND PHYSIOLOGY QUALITY OF COFFEE SEEDS  
PRODUCED IN SÃO SEBASTIÃO DO PARAÍSO-MG, BRAZIL**VIEIRA, Antônio R.\***, **OLIVEIRA, João A.\*\***, **CASTRO, Douglas G. \***

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São Sebastião do Paraíso region, in the south of Minas Gerais is an important production center. Coffee is a crop of greater social and economic importance to Brazil. Among the various sectors of the coffee production the seed sector stands out, because the seed depends on the seedlings quality and establishment of crops with yield potential. In this context, studies related to quality of arabica coffee seeds have been developed and introduced in this area.

Thus, physical and physiological quality evaluation is an important parameter to be considered in a production program, and essential to assist in decision to be taken regarding the destinies of the coffee seed lots.

The objective of this research was to evaluate the physical and physiological quality, through the germination performance, the embryo absence, the presence of brocades grains and mocha, in seeds of five coffee varieties from *Coffea arábica*.

The study was conducted using official results of coffee seeds analysis, evaluated and kindly supplied by the Central Seed Laboratory, Federal University of Lavras (UFLA), in agreement with the Agricultural Research Corporation of Minas Gerais (EPAMIG). For this purpose, it was used fresh seeds collected from cultivars: Red Catuai IAC 99, Paradise MG H 419-1, Topazio MG 1190, Yellow Catuai IAC 162 and New World IAC 379-19, produced in the years 2005/06 to 2009/10, originating from fields of coffee seed production. The variables evaluated were: germination percentage (viability through the tetrazolium test), embryo absent, brocades grain and mocha.

By the results found, it is concluded that coffee seeds produced over the years in São Sebastião do Paraíso has been of high quality and the seeds quality from cultivars Red Catuai IAC 99 and New World IAC 379-19, have been greater and more uniform over the years.

**PA 174****SUCCESSION PROCESS IN FAMILY FARMS:  
CASE STUDIES IN BRAZILIAN COFFEE FARMS****OLIVEIRA, Walber M., \*, ALMEIDA, Luciana F.\*\***

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The purpose of this paper is to investigate the succession process of family farms located in the South and Midwest area of the state of Minas Gerais – Brazil, region where ten to thirteen million bags of 60 kg of Brazilian Arabic coffee are produced annually (CONAB, 2012).

One of the characteristics of most Brazilian farms is that they belong to and are managed by one single family. The estate is an asset of the family and the production of coffee is a financial activity of considerable relevance to its members (SAES, 2009). In this context, the continuity of the business depends on the descendants' interest in working in the estate as adults. Therefore, succession should be one of the main concerns of rural estate owners and managers.

The objective of this research is to look into the way the process of succession is carried out in families who own rural estates. The specific objectives are: (i) to analyze the main aspects involving succession in family owned companies; (ii) to identify possible particularities of succession in coffee farms. Based on theoretical models of analysis of family owned companies (DAVIS et al, 1987) and on the planning of their continuity (WARD, 2004), this research, which is of exploratory nature, investigates two case studies of rural producers undergoing a family succession process. Moreover, thirty people involved in the coffee business (producers, managers of cooperatives, agronomists and specialized technicians) were interviewed in order to have their views on the topic of succession.

The results suggest that the continuity of the farm as an entrepreneurship, though desirable, is not part of the main concerns of the rural producer. The dynamics of the coffee production nowadays involves intensive use of technology, appreciation of quality attributes, environmental issues and other aspects which absorb his time and dedication. Furthermore, communication among family members over the topic of succession is highly complex. Nevertheless, preparing a successor in the family is crucial to the future of a coffee farm.

## PA 175

## PROGRESS IN BREEDING FOR DROUGHT TOLERANT COFFEE VARIETIES IN TANZANIA

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Development of drought tolerant *Coffee arabica* varieties will be a good strategy to assist these farmers especially those who are in coffee production marginal areas. Genetic improvement may sound the most appropriate approach but due to the complexity of the trait, integrated approaches may be more relevant. In this work an attempt on horticultural approach as short term solution was tried out. Several genotypes of both *Coffea arabica* and *Coffea canephora* root stock known to be drought tolerant from literature were grafted with scions from improved disease resistant *Coffea arabica* hybrid variety. The grafted seedlings together with some other lines from the breeding programme were evaluated in drought prone coffee growing marginal areas to establish their levels of tolerance. Preliminary results from these trials are reported in this work.

Key words: drought tolerance, grafting, rootstock, coffee hybrid, horticultural, global warming

## PA 176

## PROGRESS WITH SOMATIC EMBRYOGENESIS OF IMPROVED ARABICA AND ROBUSTA IN TANZANIA

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Experiments evaluate the response of different Tanzania *Coffea arabica* and *Coffea canephora* clones to multiplication by somatic embryogenesis at Tanzania Coffee Research Institute (TaCRI) from September 2009 to 2011. Fourteen genotypes were *C. arabica* hybrids and one was *C. canephora* clone. The initiation of callus followed standard procedures adopted from Nestlé Research & Development Centre, France. The research materials were fully expanded fresh leaves sampled from the trees of the selected genotypes from the field as well as at the clonal garden. The response to disinfection reflected the sources from which the initial material came from; with the ones from the clonal garden giving better results. High variation in callus formation was observed among the genotypes. Nine *C. arabica* hybrid genotypes and the *C. canephora* clone produced aqueous callus within the first month of culture. The other five *C. arabica* genotypes produced aqueous callus in the second month. Six months after culture initiation, embryogenic calluses were abundant (70-80%) in five *C. arabica* hybrids genotypes and the *C. canephora* clone. The embryogenic callus was multiplied per genotype and converted to embryos in RITA system. The somatic embryos were developed, successfully harvested, and hardened with their response to acclimatization recorded. Potted fully developed embryos were raised in the nursery for field planting. All the genotypes responded well to multiplication by somatic embryogenesis though in varying times of 4-8 months and success rate of 20-80%.

Key words: somatic embryogenesis, coffee hybrids, embryogenic callus, acclimatization

PA 177

EVALUATION OF TANZANIAN ROBUSTA COFFEE VARIETIES  
ON CUP TASTE AND BEAN SIZES**NG'HOMA, Nyabisi M.\* KUSOLWA, P.\*\* MAMIRO, Delphina P.\*\* KILAMBO, Deusdedit L.\***

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Robusta coffee is one of the most important cash crops in Tanzania. It is the source of income for more than 250,000 small scale farmers in Kagera region and accounts to 30 - 44 percent of the total export. To increase value, improvement in the bean sizes is usually essential as coffee of inferior bean sizes have negative quality. A study was therefore conducted at Maruku TaCRI sub - station in Kagera region to evaluate the variability on the bean sizes of cultivated Robusta coffee in the region. An experiment was superimposed in the coffee field established at Maruku. The design used was Randomized Complete Block Design (RCBD) with three replicates. The treatments were Bukoba1, Maruku1, Maruku2 and Muleba1. MS1 was included as a check variety. Ripe cherries were harvested, sun dried, hulled, winnowed, sorted to remove broken and black beans. Clean beans were graded using screen sieves numbers 18, 16, 14 and 12. Samples from the treatments were also subjected to beverage tasting. Results showed significant ( $P \leq 0.001$ ) variations on the bean sizes among the treatments. With sieve number 18, Robusta accessions Muleba1 had an outstanding retention of 80.7% of its beans. The results also showed significant ( $P \leq 0.001$ ) different in the bean sizes of Robusta accessions using screen sieves numbers 16 and 14. Beverage assessment of these cultivars varied with Maruku1, Maruku2, Bukoba1 and Muleba1 cups described as of natural Robusta flavour. Beverage assessment of MS1 was described as of bitter Robusta type. Varieties with high proportions retained in sieve 18 were described as of natural Robusta flavour.

Key words: Variability, Bean sizes, Coffea canephora, Tanzania

PA 178

THE NITROGEN MINERALIZATION POTENTIAL OF TWO COFFEE  
SOIL SYSTEMS OF NORTHERN TANZANIA WHEN TREATED WITH  
DIFFERENT ORGANIC MATERIALS**MARO, Godsteven P\*. MREMA, Jerome P\*\*., MSANYA, Balthazar M.\*\*, TERI, James M\*.**

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An incubation experiment was conducted at the Lyamungu Screenhouse, Tanzania Coffee Research Institute (TaCRI). Its aim was to establish the nitrogen release potential of two contrasting soil systems of Northern Tanzania, when treated with different types of organic materials. Soils were obtained from Lyamungu, Hai district, representing Eutric Nitisols of volcanic origin, and Yoghohi Prisons Farm, Lushoto district, representing Humi-Umbreic Acrisols of gneiss origin. The tested additives were cattle manure, coffee leaves, pulp and husks, Albizzia droppings and four green manure plants – Mucuna, Lupine, Canavalia and Crotalaria. They were dried, ground, sieved through a 6 mm mesh, then mixed with the soils at 5% ratio, moistened to field capacity and kept in 10 litre plastic containers arranged in Randomized Complete Block Design (RCBD), 10 treatments replicated 3 times. Fresh samples were taken at day 0, 3, 8, 15, 26, 45, 74, 112 and 180 and analyzed for Ammonia and Nitrate Nitrogen. Partial results as of day 45 were exposed to 2-way analysis of

variance under COSTAT statistical package. Soil types, organic additives and the interaction between them were all highly significant ( $p<0.001$ ). Release of mineral N was significantly higher at Yoghoi than Lyamungu. All additives gave significantly higher total N<sub>min</sub> than the untreated control which had mean of 101 mg/kg. The first four additives were *Crotalaria*, *Mucuna*, *Canavalia* and *Albizia* with mean N<sub>min</sub> of 772, 661, 564 and 551 mg/kg respectively. The last four were coffee pulp, husks, cattle manure and coffee leaves with 196, 195, 176 and 171 mg/kg respectively. Factors influencing the N mineralization of the two soils and the tested additives are discussed in this paper. The results will guide farmers in the two districts on the choice of organic materials to incorporate into their soils as an integrated soil fertility management approach.

Keywords: Mineralization, organic materials, additives, incubation

PA 179

### SURVEY FOR NATURAL ENEMIES OF COFFEE BERRY BORER, *Hypothenemus hampei* IN KILIMANJARO REGION, TANZANIA

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Coffee Berry Borer *Hypothenemus hampei* is a pest of economic importance in low to medium altitude (1000 to 1400 m a.s.l.) coffee growing areas in Tanzania. It attacks maturing coffee berries and can cause economic losses of about 60%. Possible IPM control measures include use of pesticides, cultural and use of natural enemies. While use of pesticides is always expensive and may have negative effect to the environment, cultural are cumbersome and not reliable. A survey was conducted in coffee fields' on-station at Tanzania Coffee Research Institute (TaCRI), Lyamungu to identify the availability of natural enemies infesting coffee berry borer (CBB) from April, 2010 to September, 2011. Full expanded green and ripe berries were collected in the field at the coffee trees and incubated in the incubation boxes (30cm x 30cm x 10cm) at TaCRI, Lyamungu. Unidentified parasitoids started emerging between 21 to 25 days after incubation. These were collected and preserved in 40% Formaldehyde solution in plastic vials and sent for identification at the International Centre of Insect Physiology and Ecology (ICIPE) Nairobi, Kenya. Two bethylid wasps (*Cephalonomia stephanoderis*, *Prorops nasuta*) were identified as potential parasitoids of CBB for Arabica and Robusta coffee in the study area. Additionally it was found invasive fruit flies totaling 110 were emerged from the same coffee berries and were preserved in 75% and taken to Sokoine University of Agriculture (SUA), for identification. These were identified as three fruit flies namely *Ceratitis capitata*, *Ceratitis rosa* and *Trirhithrum coffeae*. It is the first time those invasive fruit flies to be identified in coffee in Tanzania. Further research on these potential pests is recommended, as they could be a problem for our coffee in future. The information for potentiality of the parasitoids and future plans are also presented in the paper.

Key words: *Cephalonomia stephanoderis*, *Prorops nasuta*, *Ceratitis capitata*, *Ceratitis rosa*, *Trirhithrum coffeae*, natural enemies

## PA 180

COFFEE FARMING SYSTEMS, PRODUCTIVITY  
CONSTRAINTS, QUALITY AND PROFITABILITY TO  
SMALLHOLDER FARMERS IN TANZANIA**LEONARD, Kiwelu\*, JEREMIAH, Magesa\*, TERI, James M\***<sup>\*</sup>Tanzania Coffee Research Institute (TaCRI), P.O. Box. 3004, Moshi, Tanzania.

A study was conducted in 2008 to assess coffee farming systems, productivity constraints, quality and profitability to smallholder farmers in Southern and Northern Zones of Tanzania. Both primary data from 120 coffee farmers (60 from each zone) and secondary data were collected. Statistical Package for Social Science (SPSS) was used to analyse the quantitative data. It was found that the average area under coffee owned by farmers in Southern Zone was relatively small (1 ha) compared to the Northern Zone (0.8 ha) with mono-cropping system dominating in the Southern Zone as opposed to intercropping system practiced in the Northern Zone. In both farming systems it was found that, high input costs; prevalence of pests and diseases; aged coffee trees, aged coffee farmers; lack of price differential on quality to farmer who strive to increase quality; volatile coffee prices; lack of market information and prolonged drought are the major constraints to coffee productivity, quality and profitability. Meanwhile in both areas, coffee was found to be the major source of income to the households. About 33% of households' income comes from coffee, 27% from livestock; other crops 23% and off-farm sources contribute 17%. Therefore the sustainability of Tanzanian coffee industry requires addressing the challenges facing coffee sub-sector.

Key word: Coffee farming system, productivity constraints, quality and profitability

## PA 181

ASSESSMENT OF COMPATIBILITY BY GRAFTING ARABICA  
IMPROVED COFFEE VARIETIES ON ROBUSTA ROOTSTOCK  
(Promising technology towards mitigating drought problem)**MSHIHIRI, Almasi, H\*, NG'HOMA, Nyabisi, M\* and MARO, Godsteven<sup>+</sup>**<sup>\*</sup>TaCRI Maruku: P. O. Box 127, Bukoba, Tanzania<sup>+</sup>TaCRI Lyamungu: P. O. Box 3004 Moshi, Tanzania

Most of the coffee growing areas in Kagera Region, Tanzania experience 3 to 4 months of prolonged dry spell. This affects Arabica coffee production in the region as Arabica coffee requires higher amount of soil moisture than Robusta. On the other hand Robusta cultivars have an added advantage of greater root system for water absorption than Arabica cultivars. Top - working Arabica scions on Robusta rootstocks can overcome the problem. An experiment was therefore conducted to assess the compatibility of Arabica coffee as a scions onto Robusta rootstocks as a measure to support Arabica coffee production in this region. The Arabica variety used was KP423-1 as a scion grafted onto six Maruku Robusta cultivars (Selections MS1, MS2, MS3, MS4, MS5, and MS6) as rootstocks using six months old seedlings of both rootstock and scion. Grafted seedlings were maintained in humid boxes to encourage union of the scion and the rootstock. Percentage take -off was observed after 15 weeks to determine which among the grafted MS Robusta varieties has high compatibility with Arabica. Results show that, compatibility was confirmed 16 weeks after grafting. Rootstock MS 6 showed high compatibility with KP423-1 whereby the percentage take - off was more than 80 percent. The grafted seedlings are expected to be experimented in Arabica growing areas experiencing prolonged drought conditions. It is expecting the findings to mitigate drought in Arabica coffee areas in Kagera.

Key words: Compatibility, Arabica, Robusta, mitigation, drought, Kagera

## PA 182

COFFEE HERBICIDES MIXTURE AND ADDITIVE EFFECTS  
ON WEEDS IN COFFEE PLANTATION.**ALCÂNTARA, Elifas Nunes de, CUNHA, R.L da.**

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Mixtures of herbicides with other products are used in order to broaden the spectrum of action, to improve efficiency and reduce the amount of herbicides needed for weed control. The action of adjuvant such as ammonium sulfate and urea accelerates the herbicides activity by rapid foliar penetration and translocation. The effects of this salts, surfactants or herbicide mixture are variable depending on the physical and chemical characteristics of the mixtures and from weed characteristics and morphology such as differential retention, serous state, leaf age, plants nutritional status, climate and other physicochemical factors. In this context, the objective of this study was to investigate the effect of low doses of glyphosate in mixtures with other additives and test herbicides mixtures in weed control in coffee plantations. The experiment was installed at the beginning of the rainy season at the EPAMIG Experimental Station in São Sebastião do Paraíso, MG, using the IAC-99 a coffee cultivar, in randomized complete block design with four replications. The used treatments were glyphosate (1.44 kg/ ha) and (0.3kg + 2.0 kg/ ha) and (0.72 kg+ 4.0 kg/ ha), respectively, glyphosate plus ammonium sulfate), paraquat + diuron (0.6 + 0.6 kg/ ha); simazin + ametryn + (1.6 + 1.6 kg, metribuzin + 2,4-D (0.7kg + 1.75 kg/ ha), pendimethalin (1.5 kg /ha), paraquat plus urea (0.2 + 4.0 kg/ ha) plus a treatment no weeded and other weeded. There was a differential control of some weeds such as broadleaf buttonweed [*Borreria alata* (Aubl) DC.] (BOILF), which was controlled only with the pre-emergence and post-emergence applications of the metribuzin + 2,4-D. The pendimethalin did not control beggarticks (*Bidens pilosa* L.) and wild poinsettia (*Euphorbia heterophylla* L.) (EPHHL). Low glyphosate doses mixed with ammonium sulfate, were not effective in controlling broadleaf buttonweed 30 days after treatment and to areas not infested with resistant weeds, the application was technically and economically viable.

**PA 183**
**INTERCROPPING OF ALLEYS OF TREE LEGUMES WITH COFFEE PLANTS IN THE SOUTH OF MINAS GERAIS**

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The foresting coffee trees with timber tree species which adds value to the coffee crop, becomes an interesting option for increasing the local biodiversity, in addition to contributing towards the mitigation of the greenhouse effect, improving the soil moisture conditions, working as windbreaks and representing an income option to the farmer. In this context, the objective of this work was evaluating the behavior of air temperature, biomass production and the chemical composition of the different species of legumes intercropped with coffee plants. The experiment was carried out at the EPAMIG Experimental Farm of São Sebastião do Paraíso, MG, in the experimental randomized block design. The treatments evaluated were: 1- pigeon pea, 2- leucaena, 3- gliricidia and 4- acacia. The trial was constituted of strips of 5 meters broad of the different legumes planted lengthwise with five rows of coffee plants. All the plants of the trail were planted at the same time in the year of 1999. Table 1 presents the variations of temperature observed at the INET weather station in the full sunshine, close to the experimental area in the period of March to June of 2009. The results demonstrated that in the environment forested with alleys of legumes occurred reduction of the maximum temperatures of air, rise of the minimal temperatures and lower thermal ranges. After the pruning of the different legumes, the chemical composition of the biomass of each legume plant in the dry matter sample for verification of the qualitative and quantitative was determined. The results pointed out that both leucaena and acacia were the treelike legumes which presented the best results in the work. The intercropping of coffee trees with avenues of legumes represents an economic and environmental alternative to small farmers in this management system.

Table 1. Variation of the minimum, maximum, means and range (difference between maxT and the mintT) observed in a met station in area of coffee plants forested with Alleys and INMET weather station in the full sunshine at São Sebastião do Paraíso, MG, 2008.

Temperature (C)					
Treatment	Month	Minimum	Maximum	Means	Range
Station AlleysStation Full Sunshine	March	17,1	28,6	22,8	11,5
		16,3	29,0	22,7	12,7
Station AlleysStation Full Sunshine	April	16,0	27,0	21,5	11,0
		15,3	28,3	21,8	13,0
Station AlleysStation Full Sunshine	May	12,7	26,5	19,6	13,8
		11,2	25,7	18,5	14,5
Station AlleysStation Full Sunshine	June	13,1	25,1	19,1	12,0
		11,7	26,3	19,0	14,6

PA 184

## GREEN BEAN PHYSICAL CHARACTERISTICS OF PROMISING YELLOW BOURBON PROGENIES IN BRAZIL

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The overall coffee quality is associated to several physical, chemical and sensory aspects that determine the coffee prices and consumer preferences. In the specialty coffee market are preferred and more valued coffees that present outstanding cup quality and good physical characteristics emphasizing the bean size, density, shape and make. Although Bourbon variety have been reputed by its intrinsic cup quality, which is considered superior than other commercial cultivars, information regarding bean physical attributes of Yellow Bourbon coffees is very scarce in the literature. Since 1932 the Agronomic Institute (IAC) has done intensive selection on Bourbon Germplasm Collection culminating in several improved Yellow Bourbon cultivars named IACJ2, IACJ9, IACJ10, IACJ19, IACJ20, IACJ22 and IACJ24, which nowadays constitute the unique Yellow Bourbon coffees lawfully registered for planting in Brazil. Moreover, Yellow Bourbon cultivar became famous in Brazil due its high cup quality and higher yield than Red Bourbon cultivar. Aiming to select new promising Yellow Bourbon cultivar to supply the needs of the Brazilian specialty coffee producers Agronomic Institute has been studied the agronomical performance and green bean quality of advanced Yellow Bourbon progenies in different environmental conditions of Sao Paulo state. In this research it were evaluated twenty arabica coffee genotypes comprising of 17 Yellow Bourbon progenies and three Mundo Novo cultivar as control. The experiment was carried out in 2009/2010 crop year in the Northwest Region of Sao Paulo State, Brazil, in a Randomized Complete Block Design with three replications for each treatment. Fully ripe fruits were selectively handpicked from six plants of each genotype per plot and prepared by semi washed processing procedures (pulped natural coffee). The wet parchment coffees were sun dried over elevated screens until the grains reached moisture content of 11%. After hulling the clean beans were classified by size using five screens with circular perforations of 18, 17, 16, 15 and 14/64 inches sieve size and two screens with oblong perforations of 11 and 10 x ¾ inches to evaluated the beans retention. The results showed that: a) there were significant differences for large flat beans and peaberry percentages among the Yellow Bourbon progenies and control cultivar Mundo Novo; b) the differences for green bean size and shape emphasizing the possibility of to select new Yellow Bourbon progeny to improve the physical coffee quality; c) in average all genotypes showed lowest value of large flat beans and high value of medium and small flat beans. Considering that all coffees were from the same environmental conditions and processing procedures, it is supposed that the green bean physical characteristics differences could have occurred due genetic effects. Moreover, should be consider that environmental conditions in the 2009/2010 crop year were not suitable for the normal fruit and bean development, culminating in only 7% of large beans. Take into account these aspects it is reasonable infer that these genotypes should be evaluated in another crop season to elucidate the real genotype effects on bean size and shape, avoiding any inappropriate conclusion concerning the physical coffee quality of Yellow Bourbon cultivar.

**PA 185**

**MATHEMATICAL MODEL OF *HYPOTHENMUS HAMPEI* MORTALITY  
WITH TIME AT TEMPERATURE**

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*Hypothenemus hampei* is a serious pest in coffee growing areas. Identified in South Kona District of Hawaii in fall of 2010, it was soon confirmed that heavy infestations were distributed the length of the Kona coffee region with some infestation in Ka'u also. To control the spread of the beetle, these areas were placed under quarantine by the Hawaii Department of Agriculture. Under the quarantine green coffee beans are not to be shipped to other parts of the State of Hawaii without being fumigated. Transshipment through other parts of the state requires green bean coffee to be either fumigated or hermetically sealed in puncture resistant containers. The quarantine has created a significant extra expenditure of resources in addition to the loss of crop. Heat treatment for quarantine compliance could be advantageous if the temperature and time duration can be implemented with inexpensive technology such as solarization or mechanical dryers. To properly design a heat treatment for green bean coffee, a model to predict mortality with a time duration at a temperature is needed. That is the objective of this study.

A series of two level factorial experiments to estimate a gradient and line searches on the gradient estimate were used to first locate a region of high mortality at temperatures and time durations that could feasible be implemented. Then the same technique was used to find the parameters for the model of mortality over the region searched.

The mortality of *H. hampei* at a temperature for a duration of time can be modeled with five parameters. Two parameters predict the time duration for 0.50 mortality from the temperature using an inverse model (hyperbolic). Three parameters predict the standard deviation of the gaussian cumulative distribution (GCDF) of *H. hampei* time duration at the temperature using an exponential model. Mortality at the given temperature and time is predicted using the inverse GCDF using the predicted time to 0.50 as the mean, the predicted standard deviation, and the intended time duration.

Air humidity below 80% gives little additional mortality making loss of moisture of the green bean easily controlled. Mortality at 100% relative humidity is attenuated to an undesirable level and not explored. The model found in this study is for less than 80% relative humidity that is easily attained by the elevated temperature of the ambient air.

## PA 186

RAIN EFFECT ON COFFEE BERRY BORER MORTALITY PRESENT  
IN BERRIES FALLEN TO THE GROUND AT THE BRAMON  
EXPERIMENTAL STATION IN TACHIRA, VENEZUELA

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The coffee berry borer, *Hypothenemus hampei* (Coleoptera: Curculionidae, Scolytinae) is the main coffee insect pest worldwide. This insect spends the dry season, both in the remaining coffee berries left in coffee plants after harvesting and in berries fallen to the ground. At the starting of the rain season, the female adults initiate the flight activity and the infestation of new berries begins. When rain events occur during the dry season, the coffee berry borer (cbb) adults may activate its flight and die because of the lack of suitable coffee berries to be infested. In the other hand, the rain favors all those living organisms present in the soil that may affect the cbb, either eggs, larvae, pupa, or adults. Determining the mortality effect of rainfall on cbb present into the fallen berries is the main objective of this study. Every two days, starting on March 1<sup>st</sup>, both in 2010 and 2011, female adults were captured in alcohol traps, and berries picked from the soil were dissected to count cbb individuals and their health status was registered. The precipitation onsite was registered every day. Results show that the female adults captured in alcohol traps increased significantly after any rain event, especially those with a considerable amount of rain. The dissected berries or grains indicated the presence of entomopathogenic fungi in cbb adults, as well as parasitized cbb by *Cephalonomia stephanoderis* in several samples. This results prove that rain events occurred during the dry season is capable of reducing the cbb adult female population that wait for the new harvesting season, either by stimulating the flight activity before the berries are ripe enough to be infested or by increasing the natural mortality factors due to the biological activity in the humid soil. These results may help coffee growers to foresight the population of cbb just by knowing the precipitation charts or rainfall occurred in their area during the dry season and, entomologists may refine their strategies for controlling this pest based on IPM programs.

## PA 187

IDENTIFICATION OF AREAS FOR PERMANENT  
PRESERVATION IN COFFEE PRODUCING REGIONS  
OF SOUTH MINAS GERAIS, BRAZIL

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Planning for the sustainable use of natural resources requires knowledge and organization of up-to-date information about the environment. Due to the need for rural properties to comply with environmental legislation, the aim of this work was to develop a methodology to identify Permanent Preservation Areas (PPA) of hill tops and river banks occupied by coffee production. A digital elevation model of the municipality of Lambari, Minas Gerais, Brazil was created in a geographic Information System (GIS), using data from

contour and system drainage of topographic charts from IBGE. The classes of PPA studied were hill tops and river banks. A map of copy from the INPE was used to identify areas occupied by coffee production, which can be viewed on the CAFESAT website. This mapping was conducted using Lansat images from 2005 and 2006. The municipality of Lambari shows an area of 21,380 hectares (ha), out of which 2,724.66 are PPA of river banks and 4,461.26 are PPA of hill tops. The PPA represent 33.61% of the total area of the municipality, being 12.74% of riverbanks and 20.87% of hill tops. In this region, coffee occupies an area of 3,936.77 ha, corresponding to 18.42% of the total area. Coffee is present in 381.36 ha of the PPA of margins of river banks and 1,116.92 ha of hill tops. That is, it occupies 14 and 25.04% of the respective PPA. This study enabled the development of methodologies to quantify the PPA of hill tops and riverbanks, which can be used for planning sustainable mountain coffee farms and compliance with environmental legislation, especially as regards to Permanent Preservation Areas.

**PA 188****MAPPING OF AREAS FOR PERMANENT PRESERVATION IN COFFEE PRODUCING REGIONS OF SOUTH MINAS GERAIS, BRAZIL AND IDENTIFICATION OF LAND USE CONFLICTS**

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Climate changes and land use discussions has subsidized studies for soil and environmental characterization of regions. Geotechnologies have proved be a good tool for this kind of approach. The coffee consume in the world is in continuous expansion and increasing the consumer market requires for a high quality coffee. Brazil is the largest coffee producer in the world, responsible for 30% of the international market. The state of Minas Gerais highlights in the Brazilian market as the largest coffee producer. The south is the largest producer in the state. Coffee farmers in south of Minas Gerais are composed mostly by small farmers, producing at altitude areas such as hill tops and hillsides, where they have coffee of better quality. According to Brazilian forest code (Federal Law N°. 4.771/1965 and CONAMA N° 303/02), these areas are for environmental preservation. Thus, to keep a quality product, it's necessary also a sustainable techniques of production. In south of Minas Gerais, Brazil, was carried out a mapping of Permanent Preservation Areas (PPA) and coffee plantations in municipalities of Lambari, Heliodora and Jesuânia aiming to identify the land use and forest fragments. The mapping was done by ArcGis 9.2 software using as base RapidEye images. Analysis of results showed that Coffee is the second largest agricultural activity present in PPA, with few areas that have been preserved, showing low levels of compliance with resolution CONAMA N°. 303/02 the large size of Brazil and its lack of information for making decisions on the rural environment and the geotechnologies present themselves as an important tool, fast and accurate. The data discussed are pre-existing models which allows evaluating the land use serving as bases for environmental planning.

**PA 189**

**GRAFTING VS CUTTING: COMPARISON AMONG METHODS**

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*Coffea* gender has around 100 described species in which only two are economically explored, *Coffea arabica* and *Coffea canephora*. In Brazil, almost all crops that are called Robusta are Conilon Cultivar. Espírito Santo State produces 75% of Conilon national production and stands out as the major producer of this species in Brazil.

Its objective is to evaluate the grafted seedlings growth of Conilon coffee compared to those produced by cutting. It was used the graft method and the full craft grafting modality. It was held 90 days after the seed tillage. Concomitantly to the grafting process there was the planting of cuttings. The experiment was conducted at the seedling production vivarium of Incaper's Experimental Farm in Marilândia city in Espírito Santo. Seedlings from seminiferous propagation of *Coffea canephora* species, Robusta Tropical Cultivar (EMCAPER 8151) were used as rootstocks, and as graft, the Conilon Vitória Cultivar (INCAPER 8142). The cutting was held after the selection of six clones with early (8v e 12v), average (2v e 7v), and late ripeness (5v e 13v). The experimental design was totally randomized, with five repetitions composed by twelve seedlings, constituting twelve treatments. When significant differences were detected by test F, the averages were compared by Scheffé test with a probability of 5%. The grafting resulted in 91.5% of setting and the cutting showed a setting of 96.8% corroborating with previous published results that had a setting of 95 to 100% to cutting.

The superiority was detected for all growth variables of the aerial part and the root system of grafted seedlings being on more possibility for the propagation of conilon coffee and contributing to the genetic diversity of root system.

**PA 190**
**MAPPING OF COFFEE LANDS BY REMOTE SENSING**

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Understanding crop spatial distribution can help crop forecast surveys and agricultural planning. Geotechnologies have been increasingly used to assess agriculture dynamics in time and space because they allow for an accurate, timely and cost effective analysis of the territory. However, due to their particular features, automatic classification of coffee lands by remote sensing still presents difficulties and low accuracy indexes, due to the spectral similarity between coffee fields and the forest that usually occurs beside them. The aim of this work was to assess the performance of the ILWIS software supervised classification algorithms in mapping coffee lands. The study area selected was the municipality of Carmo de Minas, in the southern region of Minas Gerais state, Brazil. RapidEye images from 2012, with a 5 m spatial resolution, were used. The reference was the map generated by Zanella (2011), obtained from visual interpretation of a digital mosaic obtained from SPOT5 satellite images acquired in 2007, HCR sensor with a 2.5 m spatial resolution, and standard radiometric and geometric pre-processing (SpotMaps). This map was checked and validated on the field, presenting a 92% accuracy measured by the Kappa index.

Table 1: Distribution of land use/land occupation classes in Carmo de Minas municipality, state of Minas Gerais, Brazil.

Land use/ occupation classes	Visual classification (SpotMap)		Minimum distance (RapidEye)	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Coffee	4802,99	14,90	6610,10	20,50
Forest	8545,26	26,50	6942,22	21,53
Water	73,21	0,23	103,18	0,32
Other land uses	18822,96	58,37	18588,81	57,65
Total	32244,42	100	32244,42	100

The results found by Zanella (2011) show that coffee lands occupy 14.09%, against a 26.50% of forest, of the municipality's territory. In the classification using the RapidEye image and ILWIS software, the best result was obtained with the minimum distance classifier, which presented a 20.5% land occupation by coffee and 21.53% by forest. Despite the small percentual difference, a comparison of the distribution of these two land use classes in both maps verified, as expected, that there was some confusion by the classifier in differentiating between coffee and forest. It was concluded that SPOT and RapidEye images are adequate products to map coffee lands by digital image classification, but they require intensive checking and field validation and manual correcting of the maps generated to guarantee high accuracy levels.

## PA 191

UNDERSTANDING DRIVERS OF COFFEE YIELD QUALITY  
IN UGANDA'S COFFEE-GROWING AGRO-ECOLOGIES**JASSOGNE, Laurence\*, VAN ASTEN, Piet\*, MUKASA, David\*, WANYAMA, Ibrahim**

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Coffee is a major cash crop in Uganda accounting significantly to its export revenues. Furthermore, over 90% of the producers are smallholder farmers. Both countries and smallholders rely heavily on this commodity for living. Both yield quantity and quality determine the revenue generated from coffee production.

In this paper, we will present the results from a diagnostic survey in Uganda. The aim of this survey was to characterize constraints and opportunities in coffee smallholder systems and relate these to coffee quality. During this study, 257 coffee farmers were surveyed individually throughout Uganda. Yield parameters, biotic and abiotic constraints at plot level and socio-economic factors were either measured or asked to the farmer. Coffee quality indicators such as bean weight were recorded. Then, cupping quality, chemical analysis and Near InfraRed spectroscopy were applied on the coffee samples.

Results show a map of quality characteristics of the Robusta and Arabica coffee areas of Uganda. Yield quantity and quality were related to shade, management practices and biotic (pest and diseases) and abiotic (soil fertility) constraints.

## PA 192

IAC OURO VERDE, NEW CULTIVAR OF *Coffea arabica***FAZUOLI, Luiz C.\*, GUERREIRO FILHO, Oliveira\*, MEDINA FILHO, Herculano P.\*, GONÇALVES, Wallace\*, SILVAROLLA, Maria B.\*, BRAGHINI, Masako T.\*, MISTRO, Júlio C.\*, GALLO, Paulo B\*\*.**

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It was developed from the recombination occurred at the controlled cross between selected trees of cultivars Catuaí Amarelo IAC H2077-2-12-70 and Mundo Novo IAC 515-20. Hybridization (H5010) was held at the IAC, Campinas, SP, Brazil in 1961. The aim was to give the 'Catuaí' short size, more vigor, trying to get more productive and recombination with other favorable agronomic characteristics. In segregating generations, were selected productive plants and fruits red, continuing the selections of the descendants of these trees until the F6 generation, which was named IAC Ouro Verde, because the coffee is important in agribusiness, a true gold color green. In areas irrigated or fertilized-irrigated their average productivity ranges from 40,0 to 53.4 bags of coffee / ha / year and in areas without irrigation from 30.8 to 44.0 bags. Therefore, the trees of the cultivar IAC Ouro Verde are highly productive, but susceptible to the rust. The height of plant is short, the internodes are small and the secondary branch is abundant. The new leaves are green and/or bronze and the adult, bright dark green. The average period, from fertilization to full ripeness of the fruit is approximately 225 days. The average value of the sieve is approximately 16.5 and the percentage of seeds of the flat type is of the order of 95%. The cup quality is excellent and the share of coffee Bourbon is around 62.5%. It is important to cultivate a coffee growers and also to the family farm. Its short height allows the planting of up to 5,000 plants per hectare. It is also important in manual or mechanical harvesting and reacts well to any type of pruning. It can be used successfully in irrigated crops or irrigated-fertilized.

**PA 193**

**PARADISE FOR THE COFFEE BERRY BORER: ECONOMIC AND SOCIAL IMPACT TO HAWAII'S COFFEE INDUSTRY.**

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Hawaii is the only state in the United States that grows coffee commercially. The largest area of production is in the Kona district on the Island of Hawaii. Kona produces about 3.5 million pounds of green coffee, valued at \$35 to \$42 million annually. The Coffee Berry Borer (CBB), *Hypothenemus hampei* (Ferrari), is the main pest in coffee growing regions throughout the world. Feeding damage on the coffee seed reduces both the crop yield and quality; potentially reducing farmer's income and economic viability of the crop. CBB was reported in South Kona in August 2010 and the infestation has extended from North Kona to the district of Kau, on the south east side of the island. Climatic conditions, production practices, labor costs and the presence of feral coffee and abandoned coffee farms have made Hawaii an attractive environment for the CBB. Several farmers have stumped their coffee trees due to the devastating level of infestation. There are currently approximately 700 coffee farmers on the island of Hawaii and more than 70% of these grower report CBB infestations higher than 60%. Since the CBB has only recently invaded Hawaii, management techniques are limited and the development of a strategic plan to reduce populations is an urgent matter. Several organizations, from the state and federal government to scientific and coffee industry associations, have teamed up to combat this insect. The insect-pathogenic fungus, *Beauveria bassiana* (formulated a Botanigard, Mycotrol O) was licensed for use in February 2011 by the Hawaii Department of Agriculture (HDoA). *Beauveria bassiana* is the only commercial pesticide product available to manage the CBB in Hawaii. An overview of current state of surrounding issues, including trapping studies, the effectiveness of *B. bassiana*, as well as the economic and social impact on the Hawaiian coffee industry will be discussed here.

**PA 194**

**SEED GERMINATION OF GENOTYPES OF *Coffea arabica* L. UNDER WATER STRESS INDUCED BY PEG 6000**

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The aim of this study was to determine the effect of water stress induced by PEG 6000 in the capacity of germination of seeds of *Coffea arabica* of the genotypes Catuaí Vermelho, Obatã, Bourbon Vermelho, Mundo Novo and BA10. The study was conducted at the Centro de Análise e Pesquisa Tecnológica do Agronegócio do Café 'Alcides Carvalho', of Instituto Agronômico de Campinas, SP. Seeds of these genotypes were germinated in germination boxes with the addition of 0, 75, 100, 125, 150 g/L PEG 6000 concentrations and kept in the dark at 30 °C. Each treatment consisted of 5 repetitions with 40 seeds. Treatments were evaluated weekly for the occurrence of germination by using the criterion of radicle protrusion. In addition, it was determined the length of the rootlets of seeds of all treatments. Subsequently, 40 seeds germinated from each treatment were transplanted to pots with soil mixture and evaluated for developmental stage. From the results it was concluded that the seeds of all genotypes germinated at all concentrations of PEG 6000. However, further growth and development of seeds was different according to genotype and concentration of PEG 6000.

## PA 195

WATER STRESS IN GENOTYPES OF *Coffea arabica*

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In this study, it was evaluated the effect of water stress on vegetative growth of plants of five genotypes of *Coffea arabica*, Semperflorens, 228 BA10 C541, Catuaí 81 and Bourbon Vermelho. The study was conducted at the Centro de Análise e Pesquisa Tecnológica do Agronegócio do Café 'Alcides Carvalho', of Instituto Agronômico de Campinas, SP. The plants were obtained from seeds germinated in sand condition and subsequently kept individually in pots like soft plastic, with 1.3 kg of gravel deposited at the bottom and 3 kg of soil mix in the greenhouse. The soil mix consists of sifted soil, sand and coconut fiber (3:1:1). Treatments were applied water restriction and hydration continues when the plants of five genotypes had on average more 40 cm in height and more ten pairs of leaves. Each treatment consisted of four plants, maintained in greenhouse conditions and evaluated every seven days. The treatments were evaluated to the determination of leaf water potential, weight of the pot with the plant, soil moisture content, plant height and number of pair of leaves. The results obtained showed that the semperflorens was more resistant to treatment with water stress.

## PA 196

REDUCED SPRAYING LIQUID VOLUMES FOR *LEUCOPTERA COFFEELLA* CONTROL IN COFFEE PLANTS

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In Brazil, coffee plantations suffer a decrease in production due to infestation of *Leucoptera coffeella*, bringing the necessity of pesticides applications to control this insect, burdening production costs. This control is characterized by the use of high volumes that generate waste and pollution of the environment. With the emergence of new equipments and spray nozzles capable of producing smaller and more uniform droplets, it is possible to succeed in low volumes application, contributing to reduce expenses of the phytosanitary treatment. In area containing coffee plants in the municipality of Altinópolis - São Paulo State, previous coffee leaves collection was realized to check the level of *L. coffeella* infestation wherein it was performed spray tests with 20, 30, 40 and 200 L / ha, in comparison with conventional spray at 400 L / ha and an untreated area as control, to reduce the insect population that was presented above the level of control. The experiment design was a randomized block with four replications, performed between October 17<sup>th</sup> and November 7<sup>th</sup>, 2011. After the application, from 7 to 7 days, three samples of leaves were made in the area for each treatment. The leaves were taken to the laboratory of the Núcleo de Ensino e Desenvolvimento em Tecnologia de Aplicação (NEDTA), UNESP, Jaboticabal - São Paulo State, and were analyzed with the aid of a stereomicroscope. The variables analyzed were the number of live caterpillars and caterpillars killed. It was performed an analysis of variance and comparison of the means by Tukey test at 5% significance level for all treatments. The variables were different with respect to the different treatments, so that the treatment 200 L / ha contained the smallest number of live caterpillars and greater number of dead caterpillars for the three assessments, followed by treatment 400 L / ha. It is concluded that, even reducing the conventional spray volume by half, while maintaining the amount of active ingredient of phytosanitary products per unit area, it is possible to obtain a better result in the control of *L. coffeella* infesting coffee plants.

**PA 197**

**KINETICS OF SURFACE TENSION AND CONTACT ANGLE OF DROPLETS FROM SPRAYING LIQUIDS WITH ADJUVANTS ON COFFEE PLANT LEAVES**

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We evaluated the kinetics of surface tension and contact angle of droplets formed from aqueous spraying liquids with different chemical groups of commercial adjuvants: LI 700 (fosfatidilcoline and propionic acid), Agral (ethoxylated alkyl phenols), TA 35 (sodium lauryl ether sulphate), Veget Oil (ester fatty acids), Agridex (aliphatic hydrocarbons) and MSO (methyl ester of vegetable origin) and water on artificial (glass slide) and natural (coffee plant leaves) surfaces. The experiment was carried out at the Laboratory of the Center for Research and Technology Development Application – NEDTA, Dept. Phytosanitary - UNESP, Campus Jaboticabal-SP, Brazil, in February 2012. Fragments of leaves of coffee plant with one cm<sup>2</sup> were cut, fixed in glass slide and taken to an automatic tensiometer (model OCA-20 Dataphysics Germany), for five minutes, to obtain image analysis and using software were obtained the kinetics of surface tension and the contact angle formed between the spraying liquids and the surfaces analyzed. The data were subjected to analysis of variance by F test and the averages were compared by Tukey test at 5% probability, besides a graphical analysis. All spraying liquids with the adjuvants evaluated spread on the surface of the coffee plant leaves, therefore, the contact angles were lower at 90°. The adjuvants - LI 700, Agral, TA 35, Veget Oil, Agridex and MSO reduced the surface tension of water decreasing the contact angle between the spray and the surfaces, this caused a better wetting of the coffee plant leaves than the water, which effectively contributes to a better coverage and spray efficiency.

**PA 198**

**COVERAGE OF SPRAYING LIQUIDS IN COFFEE PLANTS SPRAYED WITH ORIGINAL AND ADAPTED EQUIPMENT FOR TALL PLANTS**

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It were evaluated the coverage of spray droplets of coffee plants by using a spray with and without a branch auxiliar for tall plants. The experiment was conducted in October 2011 in Patrocínio, Minas Gerais state, Brazil, and the experimental plots consisted of 30 plants of Catuaí 99 variety, with about 12 years old, and average height of 3.50 m. The experiment were conducted following a randomized block design with seven treatments, four replications and three spray volumes (450, 500 and 700 L ha<sup>-1</sup>). To check the distribution provided by droplets sprayed, water sensitive papers were used in one plant per plot, placed in four quadrants, and in two heights, representing the regions of the plant. After spraying in each parcel of four replicates, the papers were removed and placed in Petri dishes to keep them well away from exposure to moisture. Later, these papers were scanned and evaluated in specific program by determining the percentage of coverage. The data were statistically analyzed by F test and the averages compared by Tukey test at 5% probability. The highest coverage was observed for the spray with the auxiliary branch equipped with spray nozzles of plane jet using 500 L ha<sup>-1</sup>, significantly higher than the other treatments applied 450 L ha<sup>-1</sup> without auxiliary branch and with the extension installed to front of the equipment.

PA 199

RATE OF RECOVERY OF TRACERS USED IN  
THE MEASUREMENT OF DEPOSITION OF  
SPRAYING LIQUIDS IN COFFEE LEAVES**LASMAR, Olinto\*, FERREIRA, Marcelo da Costa\*, LORENÇON, José Ricardo\***

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In order to study the feasibility of using different micronutrients as tracers in studies of deposition of spraying liquids in coffee leaves, recovery tests were performed from stock solutions of three micronutrients. The experiments were carried out at the Laboratory of the Center for Research and Technology Development Application - NEDTA, Dept. Phytosanitary - UNESP, Campus Jaboticabal-SP, Brazil, in April 2012. The evaluated micronutrients were: manganese sulfate (31% Mn<sup>2+</sup>), copper oxychloride (50% Cu<sup>2+</sup>) and cooper hydroxide (35% Cu<sup>2+</sup>). Were added by microsyringe to adaxial surface of leaves 0.006, 0.012, 0.025, 0.05 and 0.1 mL of each suspension formed from each micronutrient in four replicates. After drying, the leaves were placed in plastic bags duly identified and then received 100 mL of a solution of 0.2 N HCl, which acted for 60 minutes to dissolve the salts used. Immediately, these extracts were filtered for quantification of ions through atomic absorption spectrophotometry, resulting in the amount of label recovered expressed in µg mL<sup>-1</sup>. The data were subjected to analysis of variance by F test and means were compared by regression test at 5% probability. The estimated results showed a recovery rate above 99% for the five micronutrients evaluated, validating the method used in coffee leaves.

PA 200

RETENTION OF COPPER HYDROXIDE SPRAYING LIQUIDS  
WITH ADJUVANTS ON COFFEE PLANT LEAVES**LASMAR, Olinto\*, DECARO JUNIOR, Sergio Tadeu\*, AZEVEDO, Letícia Henrique de\*, NEVES, Samira Scaff\*, FERREIRA, Marcelo da Costa\***

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We evaluated the retention of fungicide spraying liquids on coffee plant leaves (*Coffea arabica*) using different adjuvants. The experiment was carried out at the Laboratory of the Center for Research and Technology Development Application - NEDTA Dept. Phytosanitary - UNESP, Campus Jaboticabal-SP, Brazil, in November 2011. The treatments were based on four copper hydroxide mixtures (5 mL L<sup>-1</sup>) with the adjuvants Tensor Plus (nonilfenol), GL1 (glicerina) and Vertex RS (tributilcitrat + polidimetilsiloxano), at 1.0, 10.0 and 0.2 mL L<sup>-1</sup> dosages, respectively. Coffee plant leaves were collected and fixed on a pole attached to a precision scale. The sprayer used was fitted to CO<sub>2</sub>, at constant pressure, with hydraulic valves and two TLX2 model nozzles for small droplets production. For data collection referred to each leaf weight saturated by spraying liquids, it was adopted the 1:1 ratio (weight: volume). After the spraying, each leaf had its area measured for retention calculation in µL cm<sup>-2</sup>. The experimental design was completely randomized with four treatments and six replications. The results have shown that all spraying liquids tested acted similarly according to the amount of fungicide spraying liquid retained on coffee plant leaves.

**PA 201**
**DETERMINANTS OF CERTIFICATION ADOPTION AMONG FAIRTRADE COFFEE GROWERS IN SOUTH OF MINAS GERAIS, BRAZIL**

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Certification is an alternative to add value to coffee. In general, certified coffees do not compete directly with the commodity product, since they have different production characteristics, especially in regards to sustainability. Fairtrade is a certification that values social aspects related to coffee production. The main characteristics of the label are a minimum price guarantee, a premium payment that must be invested in the local community and disintermediation, approaching growers to buyers.

Given the importance of this certification, the objective of this study was to identify the factors that are determinant to the adoption of the label among Fairtrade coffee growers in southern Minas Gerais, Brazil. Were used data from 70 growers in the region among certified and uncertified ones. Sampling was done by convenience. Through a logistic regression analysis the variables that explain the adoption of Fairtrade were determined. Of a set of 13 variants tested, only three were significant. The results are summarized in Table 1.

Table 1 Results of Logistic Regression:

Independent Variables	Wald	Exp(B)
Constant	14,726***	00,000
Age	07,085***	02,810
CoffeePart	11,794**	03,553
Yields	09,041***	03,380
Qui-square	44,341***	
Nagelkerke R Square	00,627	

n=70; \*\*\*p<0,01; \*\*p<0,05; \*p<0,10

Growers age, coffee income participation in the family income and average yield per hectare were significant at 1% and positively related to the adoption of Fairtrade, i.e., the increase in the values of these variables increases the likelihood of being a certified grower.

The grower age is often cited as limiting to the adoption of new technologies or processes, but this is not the case of the Fairtrade certification. However, a new research would be needed to clarify this point.

The share of coffee in the family income is explained by the greater dependence of these families in getting their earnings from a single activity. This works as an incentive to make them seek for better financial results in their coffee activity, and somehow certification contributes to this effect.

Higher yield levels show higher efficiency in the activity. And in being more efficient, it is easier to the grower to adapt the certification standards.

These results can guide initiatives that seek to promote the Fairtrade certification in southern Minas Gerais, since they clearly show the ideal grower profile that is ready to adopt the label.

**PA 202**

**DEVELOPMENT OF *Hypothenemus hampei* REARED ON ARTIFICIAL DIET WITH TWO DIFFERENT PROTEIN SOURCES**

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The aim of this study was to evaluate coffee berry borer, *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae) development on artificial diet using different protein sources: torula yeast (*Candida utilis*) (20g) and brewer's yeast (*Saccharomyces cerevisiae*) (20g). Coffee berry borers were reared on Villacorta and Barrera (1993) artificial diet, with the following modifications: 150 g of coffee been powder of and 0.5 g of Vanderzant vitamin mixture for insects. The bio-essay was carried out in the laboratory of Entomology of the Instituto Agronômico do Paraná, Londrina, Brazil (25 ± 2°C, RH 60 ± 10% and complete darkness). Each diet (ca. 3.7 g) was transferred to clear glass vials (2.1 x 3.2 cm) and dried in a heater at 30°C during 48 hours (to reach 60% of humidity). Adult females obtained from coffee berries were disinfected with sodium hypochlorite solution (2%) for 2 minutes and rinsed three times in sterile water. The most active borers were individually placed into each vial (125 vials per diet) which was sealed with Parafilm®. At 10, 20, 30, 40 and 60 days after infestation (d.a.i) the number of developing coffee berry borer stages present in twenty five rearing units were recorded. The mean number of offspring per original female per vial, 40 (d.a.i), was 34.8 ± 4.43 and 25.3 ± 3.68 for insects reared on diets with torula yeast and with brewer's yeast, respectively. At 60 (d.a.i), the mean number of offspring per original female was respectively 93.6 ± 23.73 and 62.4 ± 17.56 individuals per rearing unit on diets containing torula yeast or brewer's yeast. The differences, for both dates, were not significantly different (t test, p <0.05). However, the diet with torula yeast provided faster offspring development, since males and females completed their cycle 30 (d.a.i). When brewer's yeast was used in the diet it took 40 days for life cycle completion.

**PA 203**

**AGROCLIMATIC ZONIFICATION OF COFFEE IN TACHIRA, VENEZUELA**

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Táchira was the first coffee producing state in Venezuela a few decades ago, now is ranking 4th. This situation deserves conscious analyses to identify the possible causes of the production fall, some of which are, the reduction of the cultivated area, abandoning of the coffee farms, and changes in the production systems where pastures substitutes coffee. Because of the conservationist status of coffee plantations mainly in sloppy areas where soil runoff is a big problem, there is a need to find options to regain coffee production in Táchira. The main objective of this study was to identify those zones better adapted for coffee production, including new areas as well as highly intervened watersheds where coffee would be a conservationist crop. In this study, climatic information based on precipitation maps, average, minimum and maximum temperatures, and water deficit was considered evaluating apt, moderately apt, lightly apt and non apt zones. Map algebra from

TNTmips lite software and theme classification tools were used for elaborating the maps. According to this study the appropriate region for coffee growing in Táchira is located to the south of the Andean mountainous range in the foothills to the slope of the plains and a small area located to the north of the range. The moderate region for coffee growing follows the appropriate (best) region to the south. There is also a moderate zone to the north of the mountainous range bigger than the apt region. Those zones lightly apt for coffee growing are located southward. Two potentially coffee producing axes were observed, a main one that goes from the southwest through the east at the south of the Andean mountainous range at the base of the mountains, and a minor one at the base of the range but northward.

**PA 204**

### **MARKET ANALYSIS OF BANANAS PRODUCED IN THE COFFEE PLANTATION OF SMALL PRODUCERS USING A CHAIN APPROACH IN HONDURAS**

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The market analysis of bananas produced in the coffee plantation of small producers in Honduras, focuses on the study of the bananas productive chain of the coffee plantation in Honduras. The research is based on data collected from 45 producers, 30 local traders, exporters and importers 13 and 50 consumers. The main purpose was to identify a formal and participatory way, market access alternatives that improve the small producer's incomes by selling their bananas. The research was undertaken in three phases: review of secondary information, formal market research and the participatory market research phase. This research work was developed in two coffee areas of Honduras, Peña Blanca and San Pedro of Tutule. However, it was necessary to understand the marketing mechanisms in the different markets either national or international where the coffee plantation bananas are marketed. Two productive chains were identified that sell the banana production in Guatemala, El Salvador and Honduras markets.

According to the supply that the traders handle, it reached to estimated that during the year about 766.996 coffee plantation bananas bunches, belonging 1.217 producers which associate coffee with bananas for shade and economic, as income from bananas, become an important complement to the producers, mainly in the months where there is no coffee production as well as being a product that is more dynamic in these areas economies. The margins generated in the productive chains that supply the markets, where bananas from coffee plantations is marketed, suggest that producers are complementing their income by selling bananas mainly in the months where there is no coffee production. On Peña Blanca area, farmers are receiving an average Lps. 11,226.50 per year. While in the area of Tutule this income is Lps. 6,365.71 per year.

The study shows that producers have the opportunities to improve their income from banana by improving their quality. Most traders expressed their demand for a better product and their willingness to pay higher prices according the quality it is achieved. This could be the first option to increase income by selling bananas. We also identified other marketing options such as in a formal market. However for its use, is necessary that producers have a level of organization that allows them to reach the minimum requirements in terms of volume and product quality, and get more negotiation power against traders.

## PA 205

PRODUCTIVE FORMATION OF TWO VARIETIES  
OF SMALL GROWTH SIZE OF COFFEA ARÁBICA**PINEDA, Arnold\*, MATUTE, Osmar.\*\***

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In a coffee plantation of high technological level, the present-day recommendations about densities and spacing in coffee plantations are oriented for the establishment of coffee plants with more density, for best use of the areas, as well as more productivity in few years and good profitability. Which means to start reducing the spacing between lines of coffee plant and between plants, this induces more costs, problems in the agronomical management of the plantation and a faster tissue management, meanwhile, for coffee producers with medium technological levels and especially, low production costs, like are mentioned before, limited the adoption of such recommendations. That is why, the coffee producers will always grow coffee in low densities. Otherwise, in terms of sustainability for producers in Honduras based in IHCAFE researches made in past years, a spacing of 2m x 1m is defined for a density of 3,500 plants/0.7 ha. for varieties of small growth size and 2m x 1.25m for tall growth size. They know they can have equilibrium in the production not only in costs, but also in profitability. This research was made in three places: Santa Fe, La libertad, Comayagua, at elevation 1150 MSE, Training and Research Center "Las Lagunas", Márcala, La Paz at 1440 MSE, and Rio Frio, San Nicolás, at 1348 MSE, coordinated by the Training and Research Center "José Virgilio Enamorado "linderos San Nicolás, Santa Barbará, in Honduras.C.A. Five (5) formation methods were defined: 1) Plant on axis as a witness; 2) Plants on a dual productive axis; 3) Plants using the agobio practice six months in the field; 4) Topping fifth (50) pair of leaves in nursery; 5) Final topping at six months in field and settlement of two varieties under research a) LEMPIRA (T-8667) b) IHCAFE-90 (T-5175). Some significant differences were found by variety, method and by interaction variety per methods of formation between each place on research. One alternative to reach an acceptable production, not the biggest or the best, without increasing costs, is that from one productive unit (plant) can lead to more productive axis (> leaf structure) highly efficient by prunning or planting a seedling simultaneous per bag, that permits increase productivity and profitability of the plantations, to stabilized costs and revenues to the coffee producer. Based on this research could be defined the best method of productive structure formation of plants for the two varieties of small growth size LEMPIRA e IHCAFE-90, for the coffee productive sector of Honduras.

**PA 206**

## **CHARACTERIZATION OF THE COFFEE-BANANA AGROFORESTRY SYSTEMS IN HONDURAS**

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Growing coffee in association with trees can contribute to coffee crop growth and to the diversification of farm income. Diversification may play an increasing role in the future to achieve greater system resilience, especially in Mesoamerica which is already experiencing the effects of climate change. The market plays a critical role in the establishment and maintenance of species diversity in the tree strata which acts as a disincentive to the maintenance of native species which do not have commercial value. Bananas are frequently grown in coffee agro-forestry systems by small farmers for home consumptions and national markets, being the cultivar Gross Michel the preferred cultivar for farmers. In order to characterize these systems, a diagnostic study of 30 farm households was carried out in two pilot sites in Honduras (Peña Blanca and Tutule) with an altitude range from 760 masl to 1500 masl. In each farm, two plots of 25×25 m each (1250m<sup>2</sup> per farm) were established and coffee, trees, bananas density were measured. Additionally a structured interview was conducted through farm/household visits with the owner. Results showed that coffee density varied from 1800 to 7500 plants ha<sup>-1</sup> (average 4700 plants ha<sup>-1</sup>), with an average of only 48% of productive coffee and with 50% of the farms with less than 30% of productive coffee. Over 60 shade tree species were found in the 30 farms sampled. The five most frequent tree species found were *Inga oerstediana* (16.7%), *Inga punctata* (11.3%), *Gliricidia sepium* (10.3%), *Citrus × sinensis* (8.5%) and *Cordia alliodora* (6.9%) which together accounted for over 50% of total individuals, while 22 tree species were represented by only one individual. The average tree density was 160 ( $\pm 12$ ) trees ha<sup>-1</sup>, with densities varying between 60 to 330 trees ha<sup>-1</sup>, with half as N-fixing species. The tree richness and the diversity index of Shannon of the plots were strongly related to tree density ( $r=0.69$  and  $0.59$ , respectively), but especially with tree density of non nitrogen-fixing trees ( $r^2=0.83$  and  $0.76$ , respectively). Banana mat density varied from 140-650 ha<sup>-1</sup> (averaging 300 mats ha<sup>-1</sup>) with a total pseudostems (>1m high) density varying from 370 to 2900 ha<sup>-1</sup>, which represented four pseudostems per mat (two to eight pseudostem per mat). Light transmission was from 70% ( $\pm 3$ ) for the banana stratum while it was reduced to 35% ( $\pm 3$ ) for the coffee layer, the light available for banana was strongly related to the tree stem basal area ( $r=-0.71$ ), while the light available to coffee was just poorly related to banana stems density ( $r=-0.38$ ). Based in our results, there is not a clear relationship between banana density and tree diversity; however it seems that banana pseudostem density is negatively related to tree basal area ( $r=-0.49$ ) and to coffee density ( $r=-0.56$ ). On those coffee systems minimal labor are dedicated to bananas, however at least 23% of the farmers mentioned banana income as important as coffee, additionally only 6% of the farmer expressed to be trained in banana management.

PA 207

## THREE GOOD AGRICULTURAL PRACTICES (GAP) INTERRELATED THAT CONDITION PRODUCTION ON THE COFFEE PLANT, IN HONDURAS WESTERN PART

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Production yields in the coffee crop, are conditioned by a series of activities commonly called Good Agricultural Practices (GAP), some of which are not performed due to lack of knowledge and expertise and agro climate, from the coffee area, the variety, rational use of chemicals that alter soil composition or create pest resistance, causing dependence on external inputs, or perhaps because of lack of money, all very common in our country and other countries in Central America. Three good agricultural practices are interrelated and associated with the production of coffee, such as: a) fertilization or soil nutrition, b) tissue management, c) management and rational use of tree's shadow. This work describes in terms of fertilization, regionalized formulas, liming trials, soil acidity tolerance of promising materials, increasing levels of nitrogen (N) and potassium (K<sub>2</sub>O), which serve as basis for future trials and/or sectored formulas in Honduras. It is very important to mention that nutrition corrected in the soil, one of the most important work practices that is called tissue management, commonly known as coffee growers pruning. Without this practice, the previous does not work, for which research data are provide for types, and pruning systems in four Honduras regions, along with answers found in the experimental center José Virgilio Enamorado (CIC-JVE), elevation 1440 MSE , precipitation 2010 mm, maximum temperature 25.07°C and minimum of 17.40 °C, 14° 55' 28" north latitude and 88°25'07" west length on a 1.70 m high pruning, secondary branches emission response per plant and variety, production-based in crop forecasting, using Integrated Pest Management (IPM) methodology during four harvests. In addition, to data on response for pruning of promising materials and commercial varieties. All of this is essential, however we must remember that the coffee plant requires two important factors such as air circulation and light entrance to stimulate bud serial or seeded where shade management play a big role. Comparative evaluations of Inga species are detailed, percentage of survival in the field, shade percent, weed presence and silvicultural data between coffee production under (*Cordia alliodora*) shade, Inga and full sunlight. With this presentation is intended to provide information of expertise agro ecology knowledge from coffee based in research in the Honduras western part and related to other areas of the country.

PA 208

OPTIMIZING TIMBER PRODUCTION AND CARBON STORAGE  
OF CEDRELA ODORATA AND SWITENIA MACROPHYLLA IN  
COFFEE AGROFORESTRY SYSTEMS IN HONDURAS

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Farmers throughout Honduras grow coffee primarily in association with nitrogen-fixing shade trees from the Fabaceae family. In recent decades, building on the presence of occasional timber trees in coffee plantations, the Honduran Coffee Institute has promoted the substitution of timber species for legume trees to improve farm profitability, especially during periods of low coffee prices. In such systems, unlike forests or tree plantations, timber trees may receive frequent fertilizer applications, and are spaced distant from neighboring trees to ensure adequate light for coffee production. Knowledge of species-specific timber growth rate in these systems is needed to identify optimum densities to maximize tree growth at densities with sufficient light transmission for coffee production. Coffee growers want guidelines on spacing, thinning and pruning for the different species to prepare plans for plantation design and management. Research was conducted in Comayagua and Santa Barbara, Honduras, to determine the growth and shading effects of *Cedrela odorata* (Co) and *Swietenia macrophylla* (Sm) in coffee agro-forestry systems. Tree diameter and height growth were measured in 244 coffee farms with plantations ranging from 2 to 32 years. In a subsample of 46 fields, tree distribution and dasometric characteristics were mapped and light interception measured with a densiometer in a plot of 25×25 m (625 m<sup>2</sup>). These data were used to parameterize a spatially explicit individual-based forest simulator model (SExl-FS) of light transmission and growth for multi-species agroforests. Based on analysis to define Chapman-Richards functions for each species (DBH (m) = 0.95\*(1-e<sup>-0.027\*t</sup>)<sup>1.08</sup>; r<sup>2</sup>=0.68 for Co; DBH (m) = 0.60\*(1-e<sup>-0.024\*t</sup>)<sup>1.10</sup>; r<sup>2</sup>=0.57 for Sm), Co had a greater growth rate than Sm. Additionally equations for both species differed significantly from previous equations established based on pure plantations and forests, showing that both species presented higher growth rates in agroforestry systems than in pure plantations. The model was evaluated based on comparisons of observed and predicted light levels in the mapped plots. SExl-FS accurately predicted stand-level mean canopy openness (r<sup>2</sup>=0.76, observed vs predicted). The model successfully predicted spatial variation in understory light levels (r<sup>2</sup>=0.76). Simulations ranging from 3m×3m to 12m×12m showed that increasing the tree density reduced available understory light after 3 years of growth for both species. For small farmers, wider space arrangements with 2-3 thinning appeared more suitable. Under these scenarios and with the limitation of maintaining a canopy openness higher than 50% light transmission for coffee, the model predicts a potential volume of wood for Sm of 22-29 m<sup>3</sup>ha<sup>-1</sup> and for Co of 28-32 m<sup>3</sup>ha<sup>-1</sup> after 21 years. The potential carbon storage is 11 (Sm: 100 tree·ha<sup>-1</sup>) and 22 (Co: 65 tree·ha<sup>-1</sup>) Mg C ha<sup>-1</sup>. These results can contribute to the improvement of the productivity and ecological services of coffee multi-strata agroforestry systems.

**PA 209**

**MEASURING THE CARBON FOOTPRINT  
OF COLOMBIA BUENCAFÉ LYOPHILISATE**

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While the production of freeze-dried coffee demands a good amount of energy, the sources used to get it and the efficiency of its management in Buencafé, generate a lower carbon footprint than those obtained without a strong environmental awareness in an environment similar.

In the first instance direct emissions come primarily from the combustion of natural gas that could be higher if not used coffee grounds as fuel, in this case reduces fossil fuel use by about 50% to generate the steam required for whole plant, if not delete the provision in the landfill represent an additional tons of CO<sub>2</sub>e in transport and decomposition create methane, a gas with a global warming potential 25 times greater. Moreover, the order established in the various operations of the plant to control the different sources of energy (steam, refrigeration, compressed air, electricity and fuels) are used efficiently, dramatically reducing direct emissions of greenhouse emissions associated with the product.

The results of the indirect emissions from electricity reflect the favorable condition of our country, where hydroelectric generation has a share close to 80%. Other indirect emissions can be considered, especially those that are associated with packaging materials as a way or another are part of the final product and some chemical inputs required for operations to work properly, such as refrigerants (ammonia) and sanitizers.

Given the above, the measurement of carbon footprint in the production of freeze-dried coffee, since the raw material is collected in the threshing until it reaches the port, and thanks to a robust platform and an online database synchronized with the previous one, in which all loads are considered and traceability of the product, calculations can be made permanent to emissions of greenhouse gases with a delay of only 24 hours, so you can measure continuously the effects of environmental and economic strategies used within the energy basket available.

Is then presented in this paper the application of existing national and international standards for calculating emissions of greenhouse gases, the advantages and disadvantages of its implementation and results of calculation for a specific product from the factory for a period of defined time.

**PA 210**

**EVALUATION OF SOME MULCHING MATERIALS AND THEIR  
APPLICATION METHODS ON SOIL FERTILITY IMPROVEMENT  
AND COFFEE YIELD IN GHANA.**

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The effects of some organic mulches and their methods of application on soil properties and initial coffee yield were evaluated in Ghana over a 5 year period in a randomized complete block design experiment. The treatments design were: Whole coffee plot covered with black polythene sheet; Coffee lines covered with black polythene sheet; Whole coffee plot mulched with cocoa bean shell; Coffee lines mulched with cocoa bean shell; *Flemingia macrophylla* pruned to mulch whole plot; *Flemingia macrophylla* pruned to mulch coffee lines; Live mulch with *Pueraria phaseoloides*; Whole coffee plot mulched with coffee husk; Coffee lines mulched with coffee husk; Slashing with cutlass. The organic materials were applied at the rate of 8 tonnes/ha/yr . Soil pH, soil organic carbon, total N, available P and exchangeable K contents of the soils

were determined in 1999 and 2004 and coffee yield assessed in the initial three years of bearing. The results indicate that both soil pH and soil organic C contents were not significantly affected by the treatments for both years. The soil pH generally increased over the period. Total N and Exchangeable K concentrations improved significantly in the cocoa bean shells and coffee husks treated plots. The improvements in the nutrient concentrations were higher in the plots where the coffee lines were mulched with the cocoa bean shells or coffee husks than in the whole plot –mulched treatments. The application of mulch from leguminous plants *F. macrophylla* and *P. phaseoloides* significantly ( $p<0.01$ ) decreased the available P content of the soils relative to the other treatments in both years. The combined effects of the higher contents of nitrogen, available P and exchangeable K were reflected in the initial higher coffee yield in the plots where the coffee lines were mulched with cocoa bean shells and coffee husks. The potential for utilizing cocoa bean shells and coffee husks as mulching materials is discussed.

PA 211

## EFFECTS OF WEEDS CONTROL METHODS ON COFFEE INTERROWS ON THE GROWTH OF COFFEE

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The culture of coffee is very sensitive to weed competition. The weed control in coffee rows and between rows is responsible for a high cost of production. Due to this, various weed control methods have been used as a way to minimize or eliminate weed competition on rows and coffee interrows, at compatible cost, management and yield sustainable. In order to verify the effects of several weed control methods on the coffee, was implemented in January 2006, at the EPAMIG Experimental Station in São Sebastião do Paraíso, MG, an experiment area planted with the cultivar Paradise MGH 419, using 2300 plants in the area Oxisol with 8% slope. A randomized complete block design was used with seven methods (treatments) of weed control at coffee interrows, namely: mower, harrow, rotary tiller, post-emergence herbicide (glyphosate at a rate of 720g/ ha), pre-emergence herbicide (using as pre-emergence herbicide oxyfluorfen to 3,0 liters of commercial product / ha), hand weeding and control without weeding, in three replications. The coffee rows were always kept clean by hand weeding and / or herbicide application. Several parameters about soil qualities and coffee yield in this experiment were evaluated; however, this work will be focused only on the effects on coffee growth at 2007, 2008, 2009 and 2010. The data show that treatment with pre-emergence herbicide at coffee interrows was always superior to the use of the mower, harrow, rotary tiller, post-emergence herbicide, hand hoe and the interrows with no weed control treatment, which was inferior to all other treatments, especially in the initial cropping years. It was evident that the development of coffee tends to be equal, despite the influence of weeding methods, from the fourth year of planting, eliminating in the fifth year already all the significant differences.

**Keywords:** Growth, coffee, methods of weed control.

**PA 212****INCREASE IN INCIDENCE OF BACTERIAL BLIGHT (*Pseudomonas syringae* pv. *garcae*) IN COFFEE PRODUCING AREAS IN BRAZIL**

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Since 2008 the incidence of bacterial blight, caused by *Pseudomonas syringae* pv. *garcae*, has grown in several coffee producing areas in Brazil, such as the States of Minas Gerais and São Paulo. From December 2011 to January 2012 the disease was especially severe in several coffee producing areas of these regions. The disease causes lesions in leafs, flowers and pin-head berries, and die back of twigs and branches. During this period 50 new isolates of *P. syringae* pv. *garcae* were added to the bacterial culture collection of Laboratory of Bacteriology from Instituto Biológico, Campinas, SP, Brazil. The isolates were originated from 11 towns from Minas Gerais and 15 towns from São Paulo, and were obtained from leafs, flowers, pin-head berries and branches with die back, from the cultivars Mundo Novo, Bourbon, Catuaí, Catucaí, Obatá, Acaiá, Tupi, and Icatu. Several experiments were carried out to evaluate the chemical control of the disease with coffee seedlings and in two coffee crops, in Caconde and Altinópolis in the state of São Paulo. In the seedlings the highest control of the disease was obtained with kasugamicin, followed by the treatments with copper hydroxide and copper oxychloride. In the field experiments the best results were obtained with 4 to 5 treatments with copper hydroxide (2.5 kg/ha) and copper oxychloride (4.0 kg/ha). Chemical control was more efficient in the plots less exposed to winds.



Figure 1. Symptoms of bacterial blight in leaves, branches and pin-head berries.

**PA 213****CLIMATE VARIABILITY INFLUENCES ON THE FLOWERING OF COFFEE IN COLOMBIA**

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The Colombian coffee area is influenced by several sources of climate variability at different spatial and temporal scales, one of the most important being the El Niño-La Niña (ENSO). During El Niño episodes it is common to register a reduction in the rainfall and an increase in the air temperature and sunshine; conversely during La Niña episodes increases in the rainfall and reduction in the air temperature and the sunshine are the common characteristics. Both phases of the ENSO influence directly coffee phenology and production. At the crop level, during El Niño it is frequent to observe a reduction in the seed filling specially in those zones where the soil has low water retention capacity and high crop evapotranspiration rates and during La Niña the water excess in the soil and reduction in the air temperature and sunshine produce a reduction in the number

of flower buds, delays in flower differentiation, and increased duration of flower bud latency. Between May 2008 to April 2010, weekly counts of flowers at pre-anthesis stage were realized in six branches of 30 coffee plants (two and three years old) at 8 sites across the Colombia coffee zone, between 02°24' N to 10°25' N and 1.134 m to 1.735 m of elevation; during that period two La Niña episodes and one El Niño episodes were observed. The flowering data were analysed quarterly (November-December- January, February-March-April, May-June-July, August, September, October). To relate the influence of the climate on the flowering were used the following agrometeorological indices which integrate the soil-plant-atmosphere continuum: Soil moisture indices (SMI), thermal accumulation or thermal time (TT), daily thermal amplitude (TA) and sunshine hours deficit (SD). It was observed a reduction in flowering during the La Niña directly related to periods with more than 20 days with SMI over critical values (water excess), increases in the SD (days with mean sunshine lower than 4.5 hours), and reduction in TT, and TA. During El Niño the number of flower bud increase was related to the increase of the soil water deficit (more than 60 days of moderate water deficit or 20 days with strong water deficit), reduction in the SD (days with mean sunshine over 4.5 hours), increase of the TT (more than 1.100 °C by quarter) and TA (most of 50 days by trimester with TA > 10°C). With these results were developed composite indices known as hidrothermic (HiT) and hidroheliothermic (HiHeT), which explain better the relationship between the agrometeorological conditions and flowering in coffee.

**PA 214**

**MULTIPLICATION OF COFFEA ARABICA L S.2800, AN F<sub>1</sub> HYBRID  
THROUGH SOMATIC EMBRYOGENESIS COMBINING LEAF RUST  
RESISTANCE WITH GOOD CUP QUALITY AND THEIR FIELD  
PERFORMANCE**

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Coffee is an important plantation crop in India and micropropagation can be useful for selective multiplication of superior coffee genotypes with disease resistance, high yield and good cup quality. Leaf rust caused by the fungus *Hemileia vastatrix* is a major disease of arabica coffee (*Coffea arabica* L.). Arabica is preferred over the other commercially grown robusta coffee (*Coffea canephora*) because of its superior cup quality. But arabica is susceptible to diseases and pests. Hyrido de Timor (HDT) is a spontaneous hybrid of arabica and robusta coffee and it is highly resistant to leaf rust. Bourbon is a well known arabica cultivar grown in several countries. It gives a superior quality beverage, but is highly susceptible to leaf rust. Because of this constraint, Bourbon could not be cultivated commercially in India. Realizing the importance of HDT in breeding for leaf rust resistance, several hybrid lines between HDT and other arabica cultivars were generated. Among them, S.2800 (Bourbon X HDT) is a promising F<sub>1</sub> hybrid combining disease resistance with good cup quality. In the present study, we multiplied this genotype through somatic embryogenesis and studied its performance in the field. Plants were obtained from cultured leaf tissues through high frequency somatic embryogenesis. Regenerated plants were hardened in soilrite mixture in netpots and planted along with the respective seedling progenies in the farm at Regional Coffee Research Station, Thandigudi (Tamilnadu) and some coffee grower's farms in Karnataka. The plants in the trial plots were studied for vegetative characters, yield parameters and cup quality. Somatic embryo-derived plants showed more uniformity and vigour. They attained bigger stem girth, longer primaries, and more nodes per primary and higher yield in a shorter time, compared to the seedling progeny. The cup quality was good and also leaf rust incidence was low in somatic embryo-derived plants. Severe leaf rust incidence was recorded in the seedling progenies in the trial plots in Karnataka. The results showed that clonal multiplication of leaf rust resistant F<sub>1</sub> arabica hybrids through somatic embryogenesis could maintain the true- to -type nature of the genotype and hence useful for integrated management of leaf rust.

Key words: *Coffea arabica*, F<sub>1</sub> hybrid, leaf rust resistance, somatic embryogenesis, Field performance

**PA 215**

**MORPHOLOGICAL AND MOLECULAR CHARACTERIZATION  
OF *Meloidogyne* spp. IN COFFEE PLANTATIONS OF COSTA RICA**

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In order to make a morphological and molecular characterization of the *Meloidogyne* species found in coffee plantations of Costa Rica in 2007, 100 root samples were proportionally distributed in different regions of the country. Each sample consisted of 200g of fine roots from 10 plants randomly selected from plots of 0.5-1 ha, following a zig-zag line. Information collected included geographic location, height, conditions of the plantation and data on recent applications such as product and dose.

The samples were transferred in fresh media to the Nematology Laboratory of the University of Costa Rica. The laboratory personnel determined the population density of *Meloidogyne* and *Pratylenchus*, extracted the *Meloidogyne* females for characterization and made a morphological identification by studying their perineal design. *Meloidogyne* females extracted from the roots were used for molecular characterization in the Biotechnology Laboratory of the Agronomic Research Center, University of Costa Rica. This identification was made through the Polymerase Chain Reaction (PCR) technique and PCR-RFLP analysis of mitochondrial DNA.

The samples showed high densities of *Meloidogyne*: 90 percent in the Turrialba region, 56 percent in the Central Valley, 45 percent in Coto Brus, 40 percent in Perez Zeledon, 26 percent in West Valley, 13 percent in Los Santos and, in the northern area, no samples exceeded the 20000 *Meloidogyne* J<sub>2</sub>/100g of root. In the case of the *Pratylenchus* genus, only one sample had a population density higher than 8000/100g of root. Field observations on possible aerial symptoms as chlorosis and death of branches were not clearly related to *Meloidogyne* high populations.

The morphological characterization of *Meloidogyne* identified the *exigua* species in 82 percent of the samples and *arabicida* in 4 percent. The molecular characterization identified *exigua* in 78 percent of the samples and did not identify the *arabicida* species.

**PA 216**

**POPULATION DYNAMICS OF COFFEE BERRY BORER  
(*Hypothenemus hampei*) IN THE REMAINING FRUITS ON  
THE GROUND DURING POSTHARVEST**

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The coffee berry borer populations growing in the remaining fruits left on the ground after harvest represent a serious infestation source for the next harvest. Two trials were conducted in the Perez Zeledon region and other two in the Turrialba region, both under a slightly marked dry period, during 2005-2006, with the objective of determining the behavior of the coffee berry borer populations in the fruits on the ground during the postharvest period.

Periodical evaluations were conducted on the number of fruits infected on the ground, using a 50 x 50 cm frame to make a calculation per site, and this resulted in a total of 15 sub-samples. Fruits infected were collected from the ground and taken to the laboratory; 30 fruits were randomly selected from them and dissected to determine the coffee berry borer growth stages and number. The pest attack in the following harvest and periodical capture of coffee berry borer insects in traps were registered.

The behavior of populations was similar in the four sites of the study, reaching the higher number of insect stages per fruit two or three months after the end of the harvest, until the rainy season started, which stimulated the flight of females and the activity of natural enemies, and the population gradually decreased during the

postharvest period. The flight of females under these conditions lasted for five months after harvest and the captures decreased at the same time the number of adult insects in remaining fruits decreased and the percentage of attack in the new crops increased. This study demonstrates the importance of collecting the fruits from the ground to reduce the coffee berry borer population that will attack the next crop.

## PA 217

CHEMICAL CONTROL OF *Mycena citricolor*

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The search for efficient, economically viable alternatives to the chemical control of *Mycena citricolor*, pathogen causing the disease known as Ojo de Gallo or also called American leaf spot of coffee, is a constant in the studies on chemical control for this disease, in Costa Rica. For this reason, during 2009-2010, four different mixtures of penetrating fungicides were subjected to evaluation on the control of incidence and progress of this disease. The fungicides of this evaluation: Cyproconazol + Validamycin; Tebuconazol + Triadimenol + Validamycin; AEC656948 + Trifloxystrobin; AEC656948 + Tebuconazol; and Tebuconazol + Trifloxystrobin were applied in the field, in four different coffee regions, together with Cenebol, Flint, Alcaplant and Bordeaux mixture, which were applied as well, for comparison. The best disease control was achieved with the Cyproconazol + Validamycin fungicide mixture and the Tebuconazol + Triadimenol + Validamycin mixture. Both mixtures achieved the lower incidence of disease in the four regions of the study, which was statistically different from the other treatments. Contact fungicides reached the highest development of the disease, even to total defoliation of plants. This study discusses the importance of chemical control and the choice of more appropriate products for an integrated disease management, focusing on the sustainable management of farms regularly affected by this disease in coffee trees.

## PA 218

DAILY GROWTH RATE OF *Ceratocystis fimbriata* ISOLATES ON CATURRA AND CATUAI STAKES

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Diseases in the stem of the coffee trees caused by the coffee canker known as "*Llaga macana*" are mentioned by the Costa Rican coffee growers since the early nineteenth century. Currently, this disease represents for coffee growers an increasing loss in the potential coffee yield, since the coffee trees productive life is reduced per unit area. With the purpose of learning more about the variability of pathogenicity in a sample of the population of this pathogen, the Phytopathology Laboratory of the Center for Coffee Research (CICAFE) determined the growth rate of 10 isolates of *C. fimbriata* on coffee stakes of the Caturra and Catuaí varieties. The isolates were taken from diseased coffee plants, from different regions of the country in 2008. There were no differences when comparing the average daily growth rate of the isolates studied on the stakes of the varieties evaluated and the source of the pathogen. It was indicated that the susceptibility of the coffee varieties to the *C. fimbriata* pathogen is the same of the sample analyzed. However, there were differences in the individual growth rate of each isolate, according to the genotype used as a host. This study discusses differences in the infective capacity of the isolates.

**PA 219**

**EVALUATION OF BIOLOGICAL PRODUCTS  
FOR *Mycena citricolor* CONTROL**

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Traditionally the use of chemicals to control for the Ojo de Gallo, coffee disease caused by pathogen *M. citricolor*, has been supported by technicians and coffee growers due to the effectiveness of these products. Moreover, there is not much information on biological products and the reference on commercial products is very limited. Therefore, the purpose of this study was to evaluate the residual characteristics and action of several biological products on the formation and germination of the gemmae, in the field and under controlled laboratory conditions, during 2009-2010. Two biological products were applied in the field: *Trichoderma lignorum* and *Bacillus subtilis*; while in the Phytopathology Laboratory of the Center for Coffee Research (CICAFE) the following treatments were evaluated: *Trichoderma lignorum*, a leachate from compost supplemented with molasses, *Bacillus subtilis* and the bacterial microorganisms BacLC09A, BacLC09B and P16 codes; in addition to a treatment with no application of products. The results obtained from the applications in the field indicate that the *T. lignorum* and *B. subtilis* microorganisms are not efficient in reducing the disease progress. The incidence rates of "Ojo de Gallo" with these microorganisms were statistically equal to the treatment without application of products. The results obtained in the laboratory reported a variable response of the microorganisms on the germination of *Mycena citricolor*. The best efficiency in reducing the germination of the *M. citricolor* gemmae was observed with the *Bacillus subtilis*, while the P16 code microorganism caused the lower formation of gemmae on the lesions of "Ojo de Gallo". The other treatments did not differ from the treatment without application of products. The results obtained in this experiment demonstrate the efficiency of biological products or microorganisms to control the "Ojo de Gallo" disease, although their capacity is reduced in field. For this reason, it is necessary to make more research on formulation processes to increase the permanence of these microorganisms on the plants.

**PA 220**

**EVALUATION OF TRANSMISSION OF  
*CRESPERA* THROUGH *Cicadellidae***

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In Costa Rica, the "*Crespera del café*" is a physiological disorder which symptoms are not always present in the entire plant. Sometimes, it may be possible to observe only a portion of the affected tissue in the orthotropic axes, plagiotropic branches and the leaf blades affected. Because of this behavior of the symptoms, a study was conducted in 2007, in the Phytopathology Laboratory of the Center for Coffee Research (CICAFE), to evaluate the isolated inoculation of *Xylella fastidiosa* in the coffee plants with the disorder, by *Cicadellidae* and mechanics (internodes and leafstalk) in 3-month old plants from an indirect somatic embryogenesis propagation; with the purpose of reproducing the evolution and development of the *Crespera*'s symptoms. It was determined that both the mechanical and vector inoculation methods are efficient to achieve the *X. fastidiosa* infection; however, after three months of inoculation, the more efficient infection was through vector and mechanical inoculation on leafstalks. The infection of 100% of the plants after 2 years was confirmed through DAS-ELISA. No symptoms related to "*Crespera del café*" were observed during this period. No significant differences were observed in growth between inoculated and uninoculated plants. Four years later, proliferation of secondary axes with short internodes and small, chlorotic leaves in the upper part of the main axis was observed in all inoculated plants, but not in those uninoculated. These plants were pruned in December 2011 to observe the development of shoots, corroborate the emergence of symptoms and conduct molecular studies.

## PA 221

SELECTION OF CHEMICALS FOR *Mycena citricolor* CONTROL

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It is not always possible to test in the field the effectiveness of chemicals to control the *Mycena citricolor*, because of the changes in the climatic conditions, which do not favor the development and progress of the disease and do not help to distinguish the real action of the different fungicides or chemical molecules on the formation of fruiting bodies of the pathogen or on the germination of these structures. For this reason, the effectiveness and residual activity of new molecules, fungicides and mixtures of fungicides on the formation of lesions and gemmae on residual lesions of "Ojo de Gallo" were evaluated in the Phytopathology Laboratory of the Center for Coffee Research (CICAFE), during 2009-2011. Different chemicals of contact, systemic and translaminar action were applied to plants in the field with the disease; healthy and diseased leaves were taken every week during a month and were inoculated under controlled conditions in the laboratory. The analysis of the effectiveness index of the chemicals reported a significant variability in the control capacity of the different fungicides to avoid germination and formation of fruiting bodies on the residual lesions of the disease. The results indicate that protectant fungicides in general do not have enough residual activity and effectiveness to counteract the formation of new lesions or the formation of gemmae. Translaminar chemicals showed good efficacy preventing germination of gemmae of *M. citricolor* for at least 15 days after application, but their efficiency in reducing the formation of gemmae in residual lesions was low. The systemic fungicides were not the most efficient in reducing the formation of new lesions; however, they reported higher residual activity and effectiveness to reduce gemmae formation in residual lesions of "Ojo de Gallo". The effect is more significant when Triazole fungicides with lower molecular weight are mixed with Validamycin-A. This study discusses important aspects on selecting chemicals for a correct disease management within an integrated disease management program.

## PA 222

SUBMERGED FERMENTATION OF *Beauveria bassiana*

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Since 2003, the Costa Rican Coffee Institute, through its Center for Coffee Research (CICAFE), started the production of *Beauveria bassiana* through solid substrate fermentation. This project aimed at having a biopesticide, and providing technical assistance and training to the national coffee growers for a biological control alternative that would create opportunities for the sustainable control of coffee berry borer in Costa Rica. Due to the increased demand for this biopesticide, the difficulties to obtain the solid substrate required and the increase of space, workers and time, a study was conducted in 2011 to examine the potential for production and scale up of the *B. bassiana* fungus, through the use of the liquid fermentation technique. An analysis was made considering the effect of the aeration volume and the relationship between carbon and nitrogen sources on the blastospore concentration after three days. With 8-vvm airflow and a 4:1 carbon/nitrogen relationship,  $1,0 \times 10^9$  blastopores/ml were obtained. With the blastospore arrangement in an oil-based formula, an efficient control of the coffee berry borer was achieved, statistically similar to that obtained through the *B. bassiana* conidia, produced in solid substrate.

**PA 223**

**SUSCEPTIBILITY OF DIFFERENT COFFEE GENOTYPES  
TO *Ceratocystis fimbriata***

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The *Ceratocystis fimbriata* pathogen is responsible for the most serious problems of coffee canker known as "Llaga macana" in Costa Rica. Considering the economic losses caused by this disease, a study was conducted in 2011, in the Phytopathology Laboratory of the Center for Coffee Research (CICAFE), to evaluate the susceptibility of 42 different coffee genotypes. The purpose of the study was to determine the resistance of coffee to this disease. The infection was calculated by using an isolate of *Ceratocystis fimbriata* with highest pathogenicity, according to its daily growth rate. It was observed variability in the development of *Ceratocystis fimbriata* in the orthotropic axes of the coffee genotypes evaluated. Two genotypes of *C. arabica* showed similar immunity to that observed in two accessions of *C. liberica* var. *dewevrei* used as a pattern with high resistance or immunity. Other genotypes showed a response to infection similar or higher to that of the Caturra and Catuaí varieties used as a comparison pattern. This paper discusses the potential of some coffee genotypes for a genetic improvement program to control this disease.

**PA 224**

**ABILITY OF INDOLE ACETIC ACID PRODUCING BACTERIA ISOLATED  
FROM COFFEE PLANT RHIZOSPHERE AND THEIR EFFECT ON  
ROBUSTA COFFEE SEEDLING GROWTH**

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The role rhizobacteria as a group of phytohormone producing bacteria is important in overcoming limitations of plant growth, especially estate crops, such as coffee. The bacteria potentially can be utilized in developing biofertilizers. The objective of this research was to isolate bacteria that have high capability in producing indol acetic acid (IAA) from rhizosphere of coffee trees. Sources of the isolates were rhizosphere of coffee plants planted both in Kaliwining Experimental Station, Jember Regency, and in Andungsari Experimental Station, Bondowoso Regency, both in East Java, Indonesia. The bacteria were isolated using specific medium of nitrogen free malate (NFM) and Ashby agar. Colorimetric method was used to determine IAA production. Results of this study showed that four isolates had the highest ability in producing indol acetic acid. The isolates were KwMs.1 (17.7 mg g<sup>-1</sup>), B1Ap.2.1 (16.2 mg g<sup>-1</sup>), B1Ap.1.2 (8.9 mg g<sup>-1</sup>), and B1Ap.1.1 (5.9 mg g<sup>-1</sup>). Based on characterization by phenotype test, three isolates, (KwMs.1, B1Ap.2.1, and B1Ap.1.2) had similarity to genus Azotobacter while one isolate (B1Ap.1.1) had similarity to genus Rhizobium. Based on greenhouse experiment to examine the effect of inoculation the isolates on Robusta coffee seedlings, it was shown that those isolates can improve vegetative growth the plants, in term of plant height, leaf number, stem diameter, and dry weight biomass.

Acknowledgement: This work was supported by Ministry of Research and Technology, Republic of Indonesia

**PA 225**

**UP-TO-DATE KNOWLEDGE ON THE "POTATO TASTE" OF THE ARABICA COFFEE COMING FROM AFRICAN GREAT LAKES REGION**

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The potato taste of the coffee coming from the African Great Lakes region, although of low occurrence, represents a serious risk for the coffee sector of this region. Indeed, the coffee from this region is among the best in the world and it is important to avoid this off-flavor from the produced coffee.

This off-flavor is due to the presence of the molecule: isopropyl-2-methoxyl-3-pyrazine, produced following the introduction of a bacterium of the family of Enterobacteriaceae into the cherries. The taxonomy of this unknown bacterium is presented in several phylogenetic trees. On a RNA 16S phylogenetic tree, this bacterium is close to *Escherichia coli*; on a rpoB phylogenetic tree it is near *Enterobacter agglomerans* and *Erwinia psidii*. The introduction of this bacterium is facilitated by the stings of the insect *Antestiopsis orbitalis*. Indeed, it was shown that the protection of the coffee plantations against this insect decreased the occurrence of the "Potato Taste"; on the other hand it was never shown that this insect was a vector of the involved bacterium. This assumption of vector role will have to be tested. The insect causes other damages and its aggregate distribution makes difficult the estimation of the population levels.

More work has to be done to remove this threat from the coffee of the African Great Lakes region. Hand sorting of coffee beans is effective in reducing the incidence of the potato taste and there are now modern color sorting machines highly sensitive at different coffee export companies, which detect defective beans before further cupping tests. Nevertheless, the identification of the bacterium with the new tools of molecular biology is essential and will allow a better understanding of the ecology of this bacterium in the African Great Lakes region landscape.

**PA 226**

**GENETIC DIVERGENCE BETWEEN ACCESS DILLA & ALGHE XTIMOR HIBRID AT THE GERMPLASM BANK OF COFFEE<sup>1</sup>**

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<sup>1</sup> Financial Support: Instituto Nacional de Ciência e Tecnologia do Café – INCT/Café; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Secretaria de Estado de Ciência, Tecnologia e Ensino Superior; Consórcio Pesquisa Café

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The success of coffee production in the country due to constant advances in genetic improvement in the country. The characterization of germoplasm banks, along with the study of genetic divergence provide estimates for the identification of parents who, when crossed, would increase the chances of selecting superior genotypes for use in crosses. This study investigated the genetic divergence between some accessions from the Active Germplasm Bank of Minas Gerais, installed on the Epamig, Experimental Farm in Patrocínio. There were evaluated some morphological and agronomical characters. It was analyzed 14 accessions of Dilla & Alge x Timor Hibrid using the Mahalanobis distance, and for delineation of the groups, it was used the optimization technique de Tocher and also the method UPGMA for the preparation of a dendrogram. The results showed that traits plant height, yield and maturation period were the most affected in the genetic similarity among 14 accessions tested, and also observed the formation of four groups differing in both methods, occurring partial agreement between Tocher optimization method and the UPGMA method.

**Key-words:** *Coffea arabica*, breeding, genetic dissimilarity, Minas Gerais.

## PA 227

AGRONOMIC PERFORMANCE OF COFFEE PROGENIES  
IN NATURALLY INFESTED AREA BY *Meloidogyne exigua*\*

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\* Financial support: Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Instituto Nacional de Ciência e Tecnologia do Café – INCT CAFÉ; Consórcio Pesquisa Café.

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Duo to widespread infestation of *Meloidogyne exigua* in coffee plantations, plant resistance is considered one of the main management measures of these pathogens, since it is an economical and effective method. Therefore, this work aimed at evaluating the agronomic performance of coffee progenies in order to select them in naturally infested area by *M. exigua*. The experiment was conducted in Campos Altos/MG city, Brazil. The plant material consisted of 23 progenies and seven cultivars used as control (Catuaí Vermelho IAC 99, Catuaí Amarelo IAC 62, Topázio MG 1190, Rubi MG 1192, Acaíá Cerrado MG 1474, Icatu Precoce IAC 3282 and Icatu Amarelo IAC 2942). The progenies are in the fourth generation from cross between Timor Hybrid and Catuaí, obtained from the coffee breeding program conducted by EPAMIG/UFV/UFLA in Minas Gerais State. A randomized-block design with four replications and eight plants per plot was used, in 4.0 x 0.8m spacing. The yield was evaluated in eight crops (2003/2004 to 2011/2012). The characteristics fruit at cherry stage percentage, floating beans percentage, high sieve classification, bean/fruit weight ratio and vegetative vigor were evaluated during the harvests 2010/2011 and 2011/2012. The results show that progenies 514-7-4-C130, 493-1-2-C134 and 518-2-10-C408 were the most productive over the years. The progeny 493-1-2-C134 stands out in all evaluated traits, showing to be promising for the advancement of generations.

Keywords: Timor Hybrid. Yield. Breeding.

## PA 228

IDENTIFICATION OF COFFEE PROGENIES RESISTANT  
TO *Meloidogyne exigua* UNDER FIELD CONDITIONS\*

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\* Financial support: Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Instituto Nacional de Ciência e Tecnologia do Café – INCT CAFÉ; Consórcio Pesquisa Café.

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The evaluation of behavior of coffee genotypes for resistance to *Meloidogyne exigua*, under field conditions is essential for coffee breeding programs. This work aimed to evaluate the performance of progenies in naturally infested area by *M. exigua*. Resistance nematoide progenies with superior yield were selected. The experiment was conducted in Campos Altos City, in Minas Gerais State, Brazil with 23 progenies and seven cultivars as

control (Catuaí Vermelho IAC 99, Catuaí Amarelo IAC 62, Topázio MG 1190, Rubi MG 1192, Acaíá Cerrado MG 1474, Icatu Precoce IAC 3282 and Icatu Amarelo IAC 2942). The progenies refer to the fourth generation from cross between Timor Hybrid and Catuaí obtained from the coffee breeding program by EPAMIG/UFV/UFLA conducted in Minas Gerais State. A randomized-block design with four replications and eight plants per plot in 4.0 x 0.8 m spacing. The yield was evaluated in the crops 2010/2011 and 2011/2012. The resistance of coffee trees to *M. exigua* was evaluated by number of eggs/gram of root (NEGR) and number of galls (NG) in two times, January and July 2011. The variance analysis and Skott-Knott means test were used for selection the better materials. The Pearson correlation analysis showed that parasitism of *M. exigua* in roots of coffee interferes negatively on productivity and there is a positive correlation between NG and NEGR. According to reaction to *M. exigua*, the progenies 436-1-4-C26, 514-7-14-C73, 514-7-4-C130, 493-1-2-C134, 514-7-16-C208, 493-1-2-C218 and 514-5-2-C494 are resistant.

Keywords: Coffee. Timor Hybrid. Root-knot nematode. Breeding.

**PA 229****USE OF ARBUSCULAR MYCORRHIZAL FUNGI IN PROMOTING GROWTH OF COFFEE SEEDLINGS IN CUBA.**

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In Cuba increasing interest there is focused on the response of coffee seedlings to arbuscular mycorrhizal fungi (AMF) because inoculation may constitute to viable economic alternative for efficient seedling production, decreasing the uses of fertilizers and producing vigorous plants able to better withstand environmental stresses during the acclimatization period it lives. The experiments showed that coffee seedlings respond well to AMF, inducing increases significant in plant height, dry weight, leaf area and P uptake. The differentiated effect of different AMF strains on various agriculture climatic zones. The efficiency indexes were increased with the decrease of the soils fertility. Coffee seedlings showed significantly better responses in Rodic Nitisol with the inoculation of *G. manihotis* and *A. scrobiculata*; in Chromic cambisols with *G. manihotis*; in Chromic luvisols with *G. fasciculatum* and *G. mosseae*; in Gleyic cambisoles with *G. intraradices*, *G. mosseae* and *G. fasciculatum*; in Rodic ferralsols with *G. fasciculatum* and in Rodic cambisol with *G. fasciculatum*. Results revealed that the combined inoculation of AMF + Azotobacter increased the plant height, tap root length, stem girth and dry matter weight of seedlings significantly as compared to un-inoculated control. It was determined that previous soil sterilization with methyl bromide is not necessary to obtain a positive response to AMF. It was found a significant increment in the nutritional state of the seedlings. The biggest contents of N, P K were obtained with the uses of efficient strains and in the combination soils / worm casting more appropriate to achieve bigger infection.

**PA 230****ADDITIVE MAIN EFFECTS AND MULTIPLICATIVE INTERACTION ANALYSIS FOR YIELD OF ARABICA COFFEE (*COFFEA ARABICA L.*) FROM SOUTH ETHIOPIA****GESSESE, Mesfin\*, DEMISSIE, Meaza\*\*, TAYE, Girma\*\***

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The Southern region is the second largest producer and supplier of Arabica coffee in the country and shares 46% of the national market. Coffee (*Coffea arabica L.*) grows in all parts of the region particularly in Gedeo, Sidama, Bench Maji, Shaka, Kembata-Tembaro, and Gamo Goffa administrative zones. A genotype by environment interaction experiment was conducted on 43 genotypes of Arabica coffee using RCB design with 4 replications, 2m by 2m spacing and 10 trees per plot, in two agro-ecologically contrasting locations i.e. Dale and Yirgacheffe districts of Southern Ethiopia region to evaluate the genotype by environment interaction effect of the coffee genotypes with the objective of selecting the best performing and adaptable genotype. Coffee cherry yield data was collected for 4 consecutive years in each location and analysis was computed in order to predict yield based on the selected model and evaluate and recommend high performing and adaptable varieties. Consequently, the AMMI analysis result showed a very high significant difference ( $p<0.0001$ ) of the environment, genotype and GxE interaction components. The first two principal components explained 74 % of the GxE interaction component; indicating the reasonableness and parsimoniousness of AMMI model with the first two interaction principal component axes in partitioning the treatment sum of squares effectively. The AMMI bi-plot of mean yield of the 43 genotypes showed that genotypes 1, 2, 3, 9, 32, 12, 25, 31, 10 and 29 were stable and genotypes 33, 23, 34 and 27 were most stables. In general, genotypes 1, 9, 2, 3, 32, 12 and 25 had the best performance, and genotype 1 had the high yield and was acceptably stable. The AMMI analysis was effective in identifying the best performing genotypes which the breeding program could advance.

Key words: AMMI analysis, Arabica coffee, GxE interaction, stability and South Ethiopia

**PA 231****INCOME CONTENT IN WORLD EXPORTS OF COFFEE PRODUCTS****SILVA, Orlando M., LEITE, Carlos A. M.\*,**

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Coffee is the most widely traded tropical product in international markets, with an estimated value of \$ 15.4 billion in 2009/10, when 93.4 million bags were exported. According to the ICO (2011) the number of people employed in the coffee sector was around 26 million in 56 producing and over 100 exporting countries. But what would be the position of coffee products compared to other products sold at the international markets and how they have evolved? To answer this question we calculated the annual income content of 5,111 products exported by 167 countries, between 2000 and 2009, using data from UNCOMTRADE (2011) and indicators of «sophistication» proposed by Hausmann, Hwang and Rodrik (2005), which classifies different products according to their productivity. Emphasis was given to five coffee products (coffee beans and roasted coffee,

decaffeinated or not, and soluble coffee), showing the evolution of the number of exporting countries and the level of «sophistication» (content of income), whose temporal variation was decomposed in competitiveness and income effects. The results showed that coffee, not roasted, not decaffeinated, in grains, is still the most traded product, but with the lowest income content among all coffee products, ranking in 2009, the twenty-fourth worst position in terms of income content. Roasted coffee, decaffeinated showed the largest growth in income content, placing it in 2009, 3,309 th position. The decomposition of the index showed that for coffee products with more processing, the major cause of growth in the sophistication of exports was due to the effect of Revealed Comparative Advantage. Coffee products with less processing has shown a relative loss of market share with the added value in the production chain not occurring at the producing countries at all.

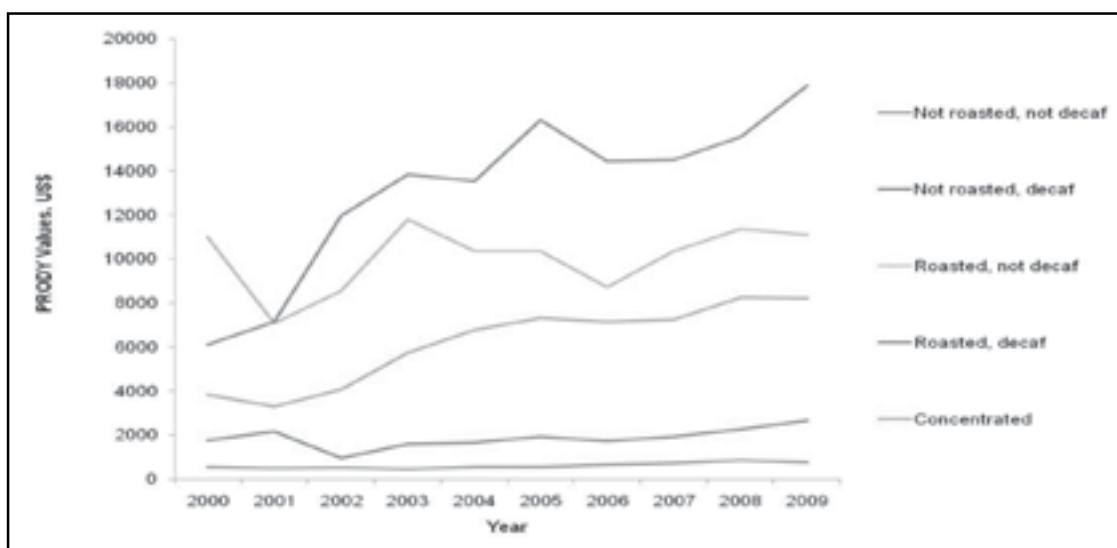


Figure 1 – Changes in income content on exports of coffee products. 2000-2009

Hausmann, Ricardo, Jason Hwang, and Dani Rodrik (2007), "What You Export Matters," *Journal of Economic Growth*, 12(1), 1-25. NBER Working Paper No. 11905.

INTERNATIONAL COFFEE ORGANISATION. [http://www.ico.org/trade\\_e.asp?section=About\\_Coffee](http://www.ico.org/trade_e.asp?section=About_Coffee)

UNCTAD – United Nations Conference on Trade and Development..COMTRADE. <http://www.unctad.org>.

**PA 232**

## MODELLING WATER MOVEMENT IN VOLCANIC ASH SOIL SLOPE OF THE COLOMBIAN COFFEE REGION

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The volcanic ash soils cover about 0.84% of land, in Colombia occupy about 11.6% of the country and the Colombian coffee region, it is estimated that about 350.000ha soil grown with coffee correspond to Andisols. These soils are characterized by hydroproperties, chemical and biological pro-growth and development of plants, which makes them considered of special interest in both the environmental and the agricultural sectors. Because the flow of water in the soil is fairly complex and difficult to measure it, and the limited information for soil slope of the Colombian coffee zone, related to soil hydraulic properties that determine such flows was a detailed study of the physical and hydraulic properties of soil and was developed and used a mathematical

model to simulate water flow in soil under conditions of slope. The first step in the investigation consisted of physical and hydrological characterization of two Andisols in soaring conditions. Soil physical and hydraulic properties were determined in each of the diagnostic horizons of 6 soil profiles. In parallel, we evaluated the volumetric moisture dynamics and the potential matrix in 6 soil profiles, over a period of wetting and drying, using the instantaneous profile method. In general, volumetric moisture declined during the first stage draw (0 - 24 hours) later, followed by a slow drainage in which the volumetric moisture changes over time were minimal, this condition is reached around day 70, the slow reduction of moisture, may be related to the high moisture holding capacity of soil, characteristic of Andisols and the presence of a horizon BW (at a depth between 80 and 120cm) that humidity remains close saturation throughout the drainage time. In a second phase, we developed a mathematical model based on Richards equation, in order to estimate the flow of water in the soil profile under conditions of hillside soils. To solve this equation was used an analytical approach, combined with the numerical method of finite differences, to apply the solution method the soil profile is discretized into a series of nodes and defined and implemented the parametric functions for retention relations humidity ( $h$ ) and hydraulic conductivity  $K(h)$ , was implemented Fredlund and Xing equation for the function  $q(h)$  and Gardner's equation for the function  $K(h)$ , the solution of the Richards model hillside soil conditions, consisted in optimizing the parameters of the functions of moisture retention and unsaturated hydraulic conductivity, then this information is estimated hydraulic functions and simulated water flows in the soil profile. The model was developed in MATLAB® program by libraries contain subroutines for calculations, which are run from a main program. The model proposed in this study allowed a quantitative description of the hydraulic properties and flow of water through the soil profile in two Andisols of the central coffee zone of Colombia. One of the biggest advantages of this model is that its conceptual basis is developed for hillside soils, and the values of process parameters are adjusted to actual conditions of water flow measured directly in the field. These field measurements were used also for the comparison of model predictions, finding that the model predicts the volumetric moisture and water flow in soil with a good level of accuracy.

PA 233

### DETERMINATION OF SOIL WATER CONDITIONS TO TRIGGERING OF MASS WASTING IN THE COLOMBIAN COFFEE REGION BY MEAN OF EXPERIMENTAL PHYSICAL MODELS

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The mass wasting affect negatively the coffee growing sustainability in the hill lands of the Colombian Andean Region. Increased landslide activity have closed relation with the change climate, especially with the increase of precipitation due to La Niña and the Southern Oscillation. For the soils of the Colombian coffee region there are few knowledge about the contributing factors of the mass wasting in relation to the soil water content. In order to contribute to this knowledge, three tons of altered soil derived from granite located in the municipality of Ibagué – Colombia were selected until the 0.16 m of depth. Seven physical slopes model according to field bulk density and soil horizons disposition were building. The dimensions of the slope model were of 1.0 m of height, with base of 1.5 m<sup>2</sup> and slope of 32°. In each model, eight suction tensimeters (0 to -85 kPa) were located. The saturation level was determined by means of the water retention curves. Rainfall simulated was applied thus: 680 mm during 34 h, 685 mm during 180 h and 150 mm during 14 h. A seepage in the head of the slope was simulated thus: Rising water level from 0.70 to 0.74 m in 8.2 h, from 0.70 to 0.75 m in 29.5 h followed of an rising from 0.75 to 0.87 m in 0.16 h and from 0.70 to 0.92 m in 1.5 h; besides a combination of

seepage and simulated rainfall were evaluated. When the rainfall of 680 mm in 34 h was simulated, the slope toe was the first sector to become to saturation and both shallow landslides and severe laminar erosion were caused. The rainfall of 685 mm in 180 h, caused the saturation of the slope toe and the fastest saturation of the subsoil. At the beginning of rainfall, the suction was increased, followed of a fall below the initial value when finalizing the same. When rainfall stopped, the suction continued its diminution in both the toe and the subsoil slope, whereas this one was again increased in the slope head section. When the rainfall started in high soil suction conditions (-300 hPa) and with presence of soil cracks produced by drying and humidification, the rainfall caused both the saturation of the toe and the superficial soil horizon. To the sub-surface flow in the head of the slope simulation, the soil failure was generated by the loss of suction of the slope tie; the failure was controlled by the permeability of the soil horizons and the changes in the soil table water. The soil and water management practices in coffee farming should prevent the soil saturation by mean of drainage systems and conservation tree planting in the toe of the slope. During long periods of drought in the coffee farming its necessary the cover crops establishment to reduce the expansion crack formation which could have slope stabilization implications.

Key words: Coffee farming, suction, landslides, soil and water conservation.



## PA 235

HERBACEOUS LEGUMES INTERCROPPING IN WEED  
MANAGEMENT OF THE BEARING COFFEE CROP

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Weed control in coffee crops demands alternative practices which contribute towards the sustainability of coffee business. The objective of this work was to determine the influence of herbaceous legumes on weeds and on coffee culture. The experiment was set in Viçosa, MG, in a Catuaí coffee crop at 19 years of age and 10 years of pruning, with 3 x 1 m spacing. It was used a random block experimental design with four replicates, consisting of eight treatments in a 3 x 2 + 2 factorial scheme, with three legume species: forage peanut (*Arachis pintoi*), siratro (*Macroptilium atropurpureum*) and lablabe (*Dolichos lablab*) and two different planting forms in the crop interrows with two and three rows of legumes spaced by 0.50 and 0.25 m apart, respectively. The two additional treatments consisted of hand weeding using a hoe and chemical control with glyphosate. It was found that the legume lablabe at 90 and 120 DAP provided the greatest soil cover, the greatest predominance of the vegetation on the weeds and the least weed infestation. Lablabe and forage peanut presented the highest biomass yield in the first year and in the second year, respectively. The greatest reduction of the density and biomass of the weeds was promoted by lablabe and siratro in the dry season and with no differences between them in the rainy period in the first year and by forage peanut in the second year. Cultivation of two or three rows of legumes did not differ among each other for soil cover, weeds and coffee crop. The legumes increased soil moisture, reduced weed infestation in the first year and increased coffee yield in the last harvest when compared to the additional treatments. There were no differences in soil moisture and coffee cultivation among the legumes and among the additional treatments. Herbaceous legumes intercropping in bearing coffee crop reduces weeds, being an alternative for integrated weed management.

## PA 236

DURATION OF THE BIOLOGICAL CYCLE OF THE COFFEE  
BERRY BORER (*Hypothenemus hampei*) IN FIELD CONDITIONS

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The duration of the biological cycle of the coffee berry borer and its reproduction depends on the temperature, which is influenced by altitude. The objective of this study was to determine the biological cycle of the coffee berry borer under field conditions in nine coffee areas of Costa Rica.

Research activities were conducted in 2002, 2003, 2004, 2006 and 2007 in Perez Zeledón (two locations), Heredia (two locations), Turrialba, Poás, Desamparados, Tres Ríos and León Cortés, in ranges from 700 to 1740 m.a.s.l. The experimental area was a plot of 0.5 ha where coffee plants were marked after the main bloom. Every 15 days, 100 infected fruits were randomly collected and 30 of them were dissected at random in the laboratory, indicating first the position of the insect in the fruit, and then calculating the number of adults, eggs, larvae and pupae in each fruit until the biological cycle was completed.

The completion time of the life cycle from egg to adult differed depending on the area and the prevailing weather conditions. In general, it was found that the cycle duration is shorter in the lower areas, while at higher altitudes the cycle needs more time to be completed. According to the results, the cycle is completed in a period of 40-45 days in areas between 700 and 1000 m.a.s.l., it will take approximately 50 days in areas between 1000 and 1200 m.a.s.l. and approximately 90 days above 1300 m.a.s.l.

The low temperatures prevailing in the coffee plantations restrict the insect growth and reduce its potential as a pest. In the low areas, with higher temperatures, reproduction is fast and damage is more severe. During the development of infected fruits, the number of stages of the coffee berry borer gradually increased inside, which caused the presence of new adults in the lower areas before the harvest, and that results in reinfestation of the crop and more damage. In areas above 1300 m.a.s.l. it is possible to start the harvest before the pest's biological cycle is completed inside the fruits.

**PA 237**

### **CHEMICAL, BIOCHEMICAL AND QUALITY VARIATIONS OF COFFEE GRAINS SUBMITTED TO DIFFERENT PROCESSING AND DRYING PROCEDURES**

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High moisture content at harvest point of coffee indicates the need of a good drying process to preserve grain quality. At this stage, moisture content is reduced from 60 to 11% (wb), being drying on the patio and/or mechanically in driers as most common processes. Variations on integrity of cellular membranes, germination, acids and sugar content, are very common at processing and drying phases. Temperature elevation at drying can damage grains, reducing coffee drink quality. The influence of slow and fast drying processes on grain physicochemical parameters and coffee drink quality have been investigated. Cultivar Catuai Vermelho IAC 44 (originally from Fazenda Experimental de Machado – FEMA, Brazil) was evaluated in three forms: natural, desmucilled and depulped coffee. The samples were submitted to slow drying at suspended screened in shadow environment, or through fast drying at fixed layer dryers, with constant temperature of 35° C to be dried to 11% (wb) moisture. After drying, coffee samples were cleaned and submitted to electric conductivity, potassium leaching, polyphenoloxidase (PFO) activity, total titratable acidity and sensorial analysis. Reduction of electric conductivity, potassium leaching and total titratable acidity, increase of polyphenoloxidase (PFO) activity and better quality of coffee were obtained when slow drying process was used, regardless the grain form tested. Regarding the grain form, natural coffee presented higher electric conductivity and potassium leaching on fast drying indicating higher probability of quality loss.

**Key words:** processing, drying, post-harvest, chemical composition, quality.

**Financial support:** CBP & D Café e Fapemig.

**PA 238**

**THE RELATIVE EFFECTS OF TRAPPING AND FIELD SANITATION ON INFESTATION LEVELS OF THE COFFEE BERRY BORER, *Hypothenemus hampei* (FERRARI), IN JAMAICA**

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Since the discovery of the coffee berry borer (CBB) in Jamaica in 1978, chemical control involving the application of endosulfan has been the preferred strategy for reducing damage associated with this pest. However, the ban imposed on the importation of endosulfan to Jamaica and general concerns about the impact of insecticides on the environment have caused a renewed emphasis on non-chemical control strategies for the management of the coffee berry borer.

Several plots of pure stand coffee were randomly selected and proper field sanitation and/or trapping of the adult coffee berry borer initiated at the start of the crop cycle and maintained for the life of the crop. During the course of the crop the level of CBB infestation and bean damage were assessed in the different plots. There was a significant difference ( $P = 0.001$ ) in the level of CBB infestation in plots where both sanitation and CBB trapping was done ( $50.0 \pm 4.9$ ) when compared to those in which sanitation only ( $33.8 \pm 5.0$ ) and CBB trapping only were done ( $25.5 \pm 4.4$ ). There was a significant difference ( $P = 0.002$ ) in the level of bean damage observed in the different plots. The percent of infested berries with greater than 4 mm bean damage was 53.3, 61.0 and 80.8, respectively, in plots in where sanitation only, sanitation and traps and traps only were employed.

**PA 239**

**AN EVALUATION OF *Beauveria bassiana* AS A NATURAL CONTROL AGENT OF THE COFFEE BERRY BORER, *Hypothenemus hampei* (FERRARI), IN JAMAICA**

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As part of an effort to diversify the control options available for use as part of a national integrated borer management (IBM) programme, the Coffee Industry Board (CIB) has been exploring the potential of *Beauveria bassiana*, which has been observed infecting the coffee berry borer (CBB) in Jamaica, as a control agent. The current study was done to assess the level of CBB infestation, the rates of infection by *B. bassiana* of CBB infesting coffee beans, as well as the level of bean damage in CBB infested beans with or without *B. bassiana* at two agro-ecologically different coffee farms.

There was no significant difference ( $P = 0.020$ ) in the level of CBB infestation was at Baron Hall ( $40.2 \pm 1.6\%$ ) and at Mountain Hill ( $44.3 \pm 1.7\%$ ). However, the *B. bassiana* infection rate of the CBB infesting the berries was significantly different ( $P = 0.007$ ;  $11.0 \pm 0.8\%$  and  $23.5 \pm 1.5\%$  at Baron Hall and Mountain Hill, respectively). The level of bean damage was significantly ( $P = 0.001$ ) lower at Mountain Hill (21.3% of infested berries) where the *B. bassiana* infection rate was  $23.5 \pm 1.5\%$  compared to Baron Hall (50.0% of infested berries) where the *B. bassiana* infection rate was  $11.0 \pm 0.8\%$ . CBB mortality was 20.3% in infested berries with no evidence of *B. bassiana* infection, compared with 100% mortality in beans with evidence of *B. bassiana* infecting the CBB.

## PA 240

THE ROLE OF IRRIGATION IN COFFEE PRODUCTION:  
A REVIEW OF RESEARCH FINDINGS IN ETHIOPIA**TESFAYE, Shimber G.**

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Erratic distribution of the seasonal rain fall, recurrent droughts and shortage of water resources for irrigation during the dry spells are among the major coffee production constraints in Ethiopia. Besides, lack or limited knowledge of effective irrigation systems makes the condition more difficult. In order to determine the optimum frequency, application method and amount of irrigation, series of experiments have been carried out under different conditions in the country. Results of these studies have indicated that watering coffee seed beds at two days interval until seedling emergence, twice a week after emergence until two to four pairs of true leaves and then at a week interval during the dry season may promote vegetative growth and dry matter yield of coffee seedlings during the nursery period. Among the different irrigation regimes, partial root zone drying (PRD) and normal deficit irrigation (NDI) significantly decreased shoot growth and total dry matter yield of young coffee plants grown in a rain shelter. On the other hand, full irrigation or well watering (WW) has resulted in considerably higher crop yield, compared to PRD and NDI. However, the difference between WW and PRD was not significant for crop yield, and yet PRD and NDI significantly improved the quality of coffee beans. In addition, PRD also saved 50% of the irrigation water required for WW and resulted in significantly higher irrigation water use efficiency (IWUE). In a separate field experiment, supplemental full irrigation (SFI) during the dry season has also resulted in higher crop yield, as compared to supplemental deficit irrigation (SDI) and a rain-fed culture, though the difference between SFI and SDI was not significant. Besides yield advantage, overall quality of the crop was substantially improved and the amount of irrigation water applied was considerably reduced by SDI compared to the SFI practice. Hence, it was concluded that PRD and SDI are effective deficit irrigation strategies that could save water, increase IWUE and improve crop quality without a significant reduction in crop yield in areas where water is scarce for irrigation and the dry spells are prolonged.

**Key words:** Irrigation, IWUE, PRD, crop growth, yield and quality

## PA 241

EARLY SCREENING OF ARABICA COFFEE GENOTYPES  
FOR DROUGHT TOLERANCE IN ETHIOPIA**TESFAYE, Shimber G.**

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In Ethiopia, coffee production is becoming increasingly constrained by changes in local weather and global climate, which brought about erratic distribution of the seasonal rain fall and recurrent droughts. Besides, shortage of water resources for irrigation during the dry spells makes the situation more difficult. In order to address the problem, genotype screening for drought tolerance has been undertaken in a rain shelter at Jimma Agricultural Research Center (JARC). Accordingly, it was observed that there were significant differences among Arabica coffee (*Coffea arabica* L.) genotypes for sensitivity to water deficit stress, rate of survival

and recovery from drought and concentration of inorganic solutes (K, Ca and Mg) in leaves. Some of the cultivars, such as F-59 and Geisha, exhibited higher rate of survival and recovery, despite higher level of sensitivity to the imposed water stress treatment. This could be probably because of higher rate of leaf shed and, thus, maintenance of lower total leaf area and specific leaf Area (SLA) (higher leaf thickness) and higher root:shoot ratio in these cultivars. On the other hand, the rate of stress development and leaf shed was lower and survival and recovery rate, as well as total leaf area was higher in cultivar 74110, 8/85 and 74112, probably because of the increased concentration of inorganic solutes, mainly K, Ca and Mg in their leaves and, hence, a more effective osmotic adjustment. Therefore, it appears that, besides scoring for the rate of stress development, leaf retention capacity, SLA, root: shoot ratio and concentration of osmoregulators, such as compatible inorganic solutes, are also important parameters to be considered during early screening of coffee genotypes for drought tolerance.

**Key words:** Arabica coffee, drought tolerance

## PA 242

### SEVERITY OF ANTESTIA BUGS, ANTESTIOPSIS SPP AND OTHER KEY INSECT PESTS UNDER SHADED COFFEE IN KENYA

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Growing coffee under shade trees has become a common practice by the farmers' especially in tropical and sub tropical countries where the effect of global warming has been heavily encountered. This practice though applied its impact on severity of key coffee insect pests; Antestia bugs (*Antestiopsis* spp), Coffee Berry Borer (CBB) (*Hypothenemus hampei* Ferri), Leaf miners (*Leucoptera* spp) and Coffee Thrips (*Diarthrothrips coffeae* Williams) on coffee has not been verified. To a certain this, study has been initiated on coffee grown under shade trees, *Cordia africana* Lam. Preliminary results have shown that the severity of *Antestiopsis* spp is significantly ( $P < 0.05$ ) higher under shaded coffee as compared to un-shaded ones with infestation (0.97 Antestia bugs per tree) to some extent attaining the economical injury level under shaded coffee. The severity of *H. hampei* and *D. coffeae*, ranged between 0.01 – 0.09% and 0.11- 0.6 thrips per leaf respectively with significantly ( $P < 0.05$ ) lower infestation observed under shaded coffee when compared with un-shaded coffee over the two cropping seasons. The infestation of coffee by *Leucoptera* spp varied from one season to the other with un-shaded coffee experiencing significantly ( $P < 0.05$ ) higher infestation during the first season, a situation that reversed in second season. Evidently, the shade effect on severity of insect pests appears to vary with different insect pest species. The implications of the current findings are discussed.

## PA 243

THE PROJECT OF COFFEE HOUSEHOLDS IN BRAZIL:  
COMMUNITY PROCESSING AND FAIR TRADE CERTIFICATION

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A set of research projects to improve coffee quality and farmers profitability has been developed with an Association of coffee households in Santo Antonio do Amparo, Minas Gerais, Brazil. The research began with the construction of a model of a Community Coffee Processing Unit. The participants coffee farmers received guidance on the application of Good Agricultural and Post- harvest Pratices. The fertilizers were applied according to leaves and soil analysis results and the phytossanitary program was based on monitoring pests and disease occurrence and use of integrated control measures as well as less toxic pesticides. Plants were harvested at the ideal time and the drying was properly conducted. Thus the association was able to sell a homogeneous batch of coffee, classified as special coffee by the SCAA (Specialty Coffee Association of America) sold to a U.S. buyer, passing up the «premium» to the grower. Nowadays the properties have been prepared for the Fair Trade certification. For that a semi-structured quiz was applied to members aiming to chek the requiriments of Fair Trade certification were being followed by the properties. Corrective measures have been taken to adapt the properties to the requirements of the certification system. A measure such as digital inclusion of producers offeringavailable training for farmers and their families has been adopted. Comparing the results obtained after the research in relation to the previous situation, the following results were obtained: improving the quality of produced coffee, increasing the income of farmers due to better marketing of coffee, increasing the autonomy of producers participating in the association due to the training that was received, improvement of the association governance with the implementation of a participatory management model.

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## PA 244

AGRONOMIC PERFORMANCE OF COFFEE CULTIVARS  
RESISTANT TO COFFEE RUST IN MINAS GERAIS STATE<sup>1</sup>

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<sup>1</sup> Financial Support: Instituto Nacional de Ciência e Tecnologia do Café – INCT/Café; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES; Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG; Secretaria de Estado de Ciência, Tecnologia e Ensino Superior; Consórcio Pesquisa Café

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The purpose of this study was to evaluate the the agronomic performance of 24 coffee cultivars (22 rust resistant cultivars 2 susceptible control varieties) in different environments of Minas Gerais aiming to recommendation these varieties in different coffee growing regions of the state. The experiments were conducted in 2005 in four municipalities (Lavras, Campos Altos, Patrocínio and Turmalina) located in three regions. The Randomized

Complete Block design (RCB) was used in the experiments, with three replications in plots measuring 3.5 x 0.7 m, with 10 plants per plot. There were evaluated the yield, the grain retained in high sieve percentage and vegetative vigor from four crops (2008/2009 to 2011/2012) and evaluation of adaptability and stability in yield by the method of Annicchiarico. The cultivars have different performance in the environments. The cultivars Sabiá 398, Pau Brasil MG1, Obatã IAC 1669-20, Catucaí Amarelo 24/137 and IPR 103 were the most promising because allied higher stability and adaptability of favorable and unfavorable environments with good agronomic performance.

**Key-words:** *coffea arabica*, annicchiarico, yield, high sieve, vegetative vigor, rust.

**PA 245**

**YIELD PERFORMANCE OF SOME ROBUSTA COFFEE  
(*COFFEA CANEPHORA* PIERRE EX A. FROEHNER) CLONES  
UNDER DIFFERENT SHADE INTENSITIES IN GHANA.**

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Coffee agroforest show beneficial features such as conservation of natural resources and stability of coffee production. At the landscape level, coffee agroforest could have mitigating impacts on climate change and biodiversity conservation. Intensive coffee management under full exposure has replaced coffee agroforest in several areas mainly as a result of low crop yields from excessive shading. Obtaining optimal coffee yields in coffee agroforest is essential to the maintenance of this cultivation method. A field trial was established in 2001 to evaluate the yield performance of ten Robusta coffee clones at four shade levels at the CRIG substation, Bunso. A split plot experimental design with four replicates was used. Stand basal area was used as surrogate for shade intensity. Secondary forest was thinned out to reach three final stand basal areas at six years after thinning as follows: 6.0 m<sup>2</sup>/ha (low shade); 9.0 m<sup>2</sup>/ha (medium shade) and 12.0 m<sup>2</sup>/ha (heavy shade). A 'no shade' control was obtained by clear-felling secondary forest. The low, medium and heavy shade levels had in addition *Gliricidia sepium* planted at 9 m x 12 m, 9 m x 9 m and 6 m x 6 m spacing, respectively. Plantain was planted at 3 m x 3 m spacing as temporary shade and coffee planted at 3 m x 2 m spacing. The main factors and their interaction had significant ( $P<0.001$ ) effect on four years cumulative clean coffee yield and 100 bean weight. Across the clones, the 'medium shade' recorded the best cumulative yield of 3,144 kg clean coffee/ha. Clone E139 under 'low shade' and clone 181 under 'no shade' produced the best (4,459 kg clean coffee/ha) and the least (1,611 kg clean coffee/ha) cumulative yields, respectively. Clone E90 recorded the best bean weight (15.3 g/100 beans) across the different shade levels. Clone E139 under 'medium shade' had the largest bean weight (16.9 g/100 beans). The 'no shade' treatment across the clones recorded the least bean weight (13.4 g/100 beans). The significant clone x shade interaction shows that Robusta coffee production can be optimised in a coffee agroforest by matching coffee clones with appropriate shade levels.

PA 246

SHIKIMIC ACID ACCUMULATION AND PLANT INJURY IN *COFFEA ARABICA* AFTER SIMULATED GLYPHOSATE SPRAY DRIFT EXPOSURE**SCHRÜBBERS, Lars\***, **SØRENSEN Jens Christian\***, **VALVERDE, Bernal E.\*,\*\***, **CEDERGREEN, Nina\***

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Glyphosate is one of the world's most ubiquitously used and important herbicides. It is commonly used in coffee plantations to combat weeds that compete with the crop for resources such as light, water and nutrients. Glyphosate is a non-selective, broad spectrum herbicide thus possessing the risk of crop injury through unintended crop exposure from spray drift. Once taken up, glyphosate inhibits the enzyme 5-enolpyruylshikimate-3-phosphate synthase (EPSPS) which leads to, besides visible symptoms, an accumulation of shikimic acid in plant tissue.<sup>1</sup> Low spray drift exposure has shown to decrease yield in various crops.<sup>2-4</sup> Coffee plants are negatively affected by sub-lethal doses,<sup>5</sup> though references on yield reduction or shikimic acid levels have not been found. In this study, we measured growth and shikimic acid levels in coffee leaves, following greenhouse based spray-drift simulations (2.5 - 40% of a field dose; 1080 g a.e./ha) and evaluated both its potential as a biomarker for long-term exposure, as well as a molecular marker for plant injury. Preliminary results indicate a decrease in the height growth rate as early as 2 weeks after the exposure but returning to the regular rate (compared to control plants) 6-8 weeks post-exposure; however, a reduction in total height was still present after 8 weeks. Shikimic acid, accumulated 2 weeks after glyphosate application but no accumulation could be detected after 8 weeks. Analysis of this trend is currently underway, to support the assumption that shikimate accumulation is limited to a time period of 2 to 4 weeks as well as to investigate if shikimate levels are affected by leaf sampling at different height/age of the coffee plant. Besides the potential yield loss even a change in the chemical composition<sup>6</sup> of the coffee beans might be possible, if plants are exposed within 2-4 weeks before harvest.

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**PA 247**
**COFFEE TREES IN FORMATION UNDER DIFFERENT RADIATION  
LEVELS: MORPHOPHYSIOLOGICAL CHARACTERISTICS AND THE  
CERCOSPORIOSIS INCIDENCE**

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Differences in the radiation availability may cause changes in the structure and functionality of coffee trees leaves. The aim of this paper was to evaluate the morphological mechanisms and the cercosporiosis incidence in coffee trees in formation under different radiation levels. After planted in the field, the coffee tree underwent five different radiation levels (full sunlight and plastic screens/sombrites at 35, 50, 65 and 90% shade levels). The evaluation of the morphological characteristics and cercosporiosis incidence begun 10 months after the installation in the test field. Under high luminosity and low water availability conditions, the coffee leaves have greater thickness of the cuticle adaxial face. The increase of the radiation availability causes the increase of the leaf thickness and stomata density, besides the reduction of the stomata size of coffee trees in formation phase. These changes potentially favour the photosynthesis process up to the 65% shade level, the 30% shade level being the most recommended. At each 10% increase in the shade level, there is reduction of about 5% in the photosynthesis rate and 10% in the cercosporiosis incidence in coffee trees in the formation phase (Table 1). These results show that the amount of incident radiation is important for the development of the coffee leaves internal structure that may favor the physiological characteristics needed to optimize this culture growth under shade.

Table 1. Regression equations and determination coefficients ( $R^2$ ) for the variables photosynthetic rate, leaf thickness, palisade parenchyma thickness, stomata density and area under the disease progress curve in coffee trees in formation under different radiation levels during the dry and rain seasons.

Variable	Regression equations	$R^2$
Dry season		
Photosynthetic rate	$y = 5,2829 - 0,028242x$	0,74**
Leaf thickness	$y = 481,3686 - 0,840125x$	0,96**
Palisade parenchyma thickness	$y = 91,973 - 0,26066x$	0,92**
Stomata density	$y = 80,3377 - 0,380648x$	0,97**
Rain season		
Photosynthetic rate	$y = 6,5280 - 0,037396x$	0,86**
Leaf thickness	$y = 449,287 + 0,6002x - 0,012387x^2$	0,91**
Palisade parenchyma thickness	$y = 81,099 + 0,082x - 0,00237x^2$	0,97**
Stomata density	$y = 102,343 - 1,17997x + 0,00686x^2$	0,93**
Dry and rain seasons		
Area under the disease progress curve	$y = - 0,034x^2 + 6,601x + 376,8$	0,96*

\*\*Significant at 1% and \*significant at 5% of probability by F test.

**PA 248**
**COFFEE TREES IN PRODUCTION UNDER DIFFERENT RADIATION LEVELS: MORPHOPHYSIOLOGICAL CHARACTERISTICS**

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The suitability of plants from the same species to the different radiation conditions is associated to the physiological and anatomical characteristics. There is little information about the mechanisms related to the morphological plasticity displayed by the coffee tree acclimated to different environments. In this context, the aim of this paper was to evaluate the morphological mechanisms in coffee trees in production under different radiation levels. After crops pruning and the first production, the coffee trees were subjected to five different radiation levels (full sunlight and under plastic screens/sombrites at 35, 50, 65 and 90% shade). The plants were evaluated concerning the gas exchanges, chlorophylls contents, nitrogen content and leaf anatomy during rainy and dry seasons, 8 and 15 months after the experiment instillation, respectively. In coffee trees in production phase the radiation levels change very little in the chlorophyll full content and the a/b chlorophylls proportion. The increase of the radiation availability causes the increase of the leaf thickness and stomata density, besides the reduction in the stomata size of coffee trees in the production phase. These changes potentially favour the photosynthesis process up to 50% shade level, the 20% shade level being the most recommended. The highest photosynthesis rate occurs in 21% and 26% shade levels, under low and high water availability in the soil, respectively (Table 1). These results show that the amount of incident radiation is important for the development of the coffee leaves internal structure that may favor the physiological characteristics needed to optimize this culture productivity under shade.

Table 1. Regression equations and determination coefficients ( $R^2$ ) for the variables photosynthetic rate, leaf thickness, palisade parenchyma thickness and stomata density in coffee trees in production under different radiation levels during the dry and rain seasons.

Variable	Regression equations	$R^2$
Dry season		
Photosynthetic rate	$y = 4,669 + 0,0387x - 0,00093x^2$	0,93**
Leaf thickness	$y = 475,428 + 0,1869x - 0,009446x^2$	0,96**
Palisade parenchyma thickness	$y = 114,329 - 0,3160x$	0,83**
Stomata density	$y = 97,950 - 0,5372x$	0,98**
Rain season		
Photosynthetic rate	$y = 3,799 + 0,035x - 0,00068x^2$	0,88**
Leaf thickness	$y = 436,256 - 0,5451x$	0,84**
Palisade parenchyma thickness	$y = 78,453 - 0,2313x$	0,89**
Stomata density	$y = 81,064 - 0,3833x$	0,91**

\*\*Significant at 1% of probability by F test.

## PA 249

## LINKING INJURY PROFILES IN COFFEE-BASED AGROFORESTRY SYSTEMS WITH PRODUCTION SITUATIONS: CASE STUDIES IN COSTA RICA

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An injury profile is a combination of injury levels caused by different pests and diseases. A production situation is defined as the combination of factors (physical, biological and socio-economic) determining agricultural production. Linking injury profiles with production situations is (i) a way to identify factors influencing pests and diseases development and (ii) a first step when assessing crop losses.

We used data from Avelino et al. (2007) where 91 coffee plots from Costa Rica were characterized by assessing 43 variables describing the topo-climatic conditions, the crop management, and the coffee plant characteristics. The incidence of 11 pests and diseases was also evaluated. Four production situation patterns and four injury profiles were identified by cluster analyses. Production situations were significantly correlated to injury profiles according to the mantel test. The production situations characterized by high altitude and low shade level were associated with the injury profile that presented very low incidences of all pests and diseases. The injury profile with the highest incidences (high level of coffee rust, brown eye spot disease, thread blight, dieback and root knot nematode) was associated with systems of low altitude with high shade level. In medium altitudes, technified systems (high coffee plant density, high number of fertilizer applications and low shade cover) were associated with high levels of American leaf spot disease, coffee blight and root lesion nematodes, whereas systems poorly technified (more than 16% of shade cover, low number of fertilizer applications and low density) were associated with high levels of leaf miner and ceratocystis canker.

We demonstrated that injury profiles were determined by topo-climatic conditions in interaction with the cropping practices, and particularly shade cover. From our data we deduced that shade effects on pests and diseases are pest and altitude specific. Therefore, crop management and particularly shade cover management should be adapted to the topo-climatic conditions to reduce highly damaging pests and diseases.

In addition, this could have implications when ecosystem services are considered. Indeed, trade-offs between service of pest and disease regulation and services associated to shade (biodiversity, carbon sequestration) depend on the production situation. It means that all production situations are not equal in terms of costs and gains with respect to ecosystem services provision.

Avelino, J., Cabut, S., Barboza, B., Barquero, M., Alfaro, R., Esquivel, C., Durand, J.F., Cilas, C., 2007. Topography and crop management are key factors for the development of American leaf spot epidemics on coffee in Costa Rica. *Phytopathology* 97, 1532-1542.

## PA 250

DAMAGE OF ARABICA COFFEE CAUSED BY COFFEE WHITE STEM BORER (*Xylotrechus quadripes*) IN INDONESIA.**WIRYADIPUTRA Soekadar \***

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Coffee white stem borer (CWSB, *Xylotrechus quadripes*) well known as a main coffee pest in India and causing significant losses of production on Arabica coffee. It is very important insect pest in Arabica coffee and difficult to control. The pest together with coffee berry borer as main causing agent for decline of India's coffee exports in the 2011-2012 crop year as amount of 16.7 %. In an estate of Arabica coffee in East Java, with acreage of around 1348 ha, has been infested with CWSB of about 206.2 ha or about 15,3 %, and total number of coffee trees infested is more than 2.61 million. Expanding and heavy infestation of CWSB in that estate is presumed

in connection with the opening of shade trees during last decade. As stated in several references that the beetles are active during bright and hot weather. Female beetles lay eggs in the cracks and crevices of the bark and under the loose scaly bark of the main stem and thick primaries, preferring the plants exposed to sun light. Preliminary trial with trapping using pheromone trap produced by PCI, India, revealed that the male beetles attracted the trap. Installation of five traps during three weeks has been caught 24 beetles of the pest. It was indicated that pest species found in East Java is same with CWSB infested coffee in India. In the future, it needs deeper study of many aspects the pest in Indonesian conditions.

PA 251

### IMPORTANCE OF PLANT MATERIAL IN THE FIGHT AGAINST THE COFFEE BERRY BORER (*Hypothenemus hampei* Ferrari)

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A study on the attacks of coffee berry borer *Hypothenemus hampei* Ferrari, was performed on the research station of Divo in Côte d'Ivoire, to develop integrated control methods against this pest of coffee. This study was set up according to an experimental Split split plot design, with four repetitions; the first factor was the sanitary harvesting, the second, the association of leguminous trees and the third, the variety of coffee. The data were processed according to the phenological stages of the coffee tree characterized by quarter. Overall, for all phenological stages, sanitary harvesting did not influence the production of green and ripe fruit and their attack by the berry borer. Similarly, the association of tree legumes to coffee had no effect on the production of green and ripe fruit and their attack by the berry borer. On the other hand, the studied clones had productions of green and ripe fruits and attacks of berry borer different at the level of all the quarters. For quarters bound to the fruiting, the clone 461 with 63,45 green and ripe fruits by twig in the second quarter and 59,70 for the third quarter obtained the biggest production of fruits. On the other hand, the clone 477 had the lowest production of fruits with 22,98 green and ripe fruits by twig in the second quarter and 32,81 for the third quarter. For quarters bound to the attacks of fruits by the berry borer, the clone 477 which had the lowest production of fruits, was the most attacked with 40,41pc. in the first quarter and 7,91pc. for the second quarter; on the other hand, the clone 461 which had the strongest production of fruits, was the least attacked with 25,96pc. in the first quarter and 0,69pc. for the second quarter. A higher number of fruits per branch indicates the character more grouped of production while a lower number shows the character more sporadic and spread of production, favorable to coffee berry borer attacks. The nature of plant material seems crucial in the fight against the coffee berry borer. The length of the production cycle and the more or less grouped flowering are factors that influence the presence of berry borer in coffee, making most other control methods ineffective.

**Keywords:** Coffee, Clones, Production, Phenology, Coffee berry borer, *Hypothenemus hampei*, Attacks.

**PA 252****PROFILE FROM RURAL PROPERTIES OF FAMILY ASSOCIATION'S COFFEE PRODUCERS IN THE SOUTH OF MINAS GERAIS/BRAZIL REGARDING TO GOOD AGRICULTURAL PRACTICES AND MANAGEMENT IN THE COFFEE CULTURE (*COFFEA ARABICA L.*)**

**PEREIRA, Sérgio P.<sup>2</sup>; ROSA, Beatriz T.<sup>3</sup>; GUIMARÃES, Rubens J.<sup>4</sup>; AGUIAR, Cibele M.G.<sup>5</sup> de.; ROMANIELLO, Marcelo M.<sup>4</sup>; SILVA, Edimilson E.<sup>6</sup>**

1 - Integral part of project sponsored by the Foundation for Research Support of Minas Gerais - FAPEMIG and ongoing thesis of the first author at the Federal University of Lavras – UFLA; 2- Researcher at the Agronomic Institute of Campinas – IAC; 3 - Scholarship FAPEMIG; 4 - Professor of UFLA; 5 - Journalist of UFLA; 6 - Manager Incubacoop UFLA.

The «Good Agricultural Practices and Management» (BPAGs) consist in the technologies adoption and processes available for agricultural production aiming the economic viability, social justice and using natural resources sustainably, bringing healthy products and free of residues. The aim of this study was to evaluate coffee producers profile from Family Producers Association of Santo Antonio do Amparo (AFASA) in south part of Minas Gerais state - Brazil, concerning to "Good Agricultural Practices and Management", allowing the division into distinct groups according to their performance. AFASA raised from a project called "Coffee Force", sponsored by Hanns R. Neumann Stiftung of Brazil Foundation, connected to Neumann Kaffee Gruppe. The research justify itself in order to propose different actions of technical assistance and rural extension directed to different groups within the association. The research was lead by 33 coffee producers (total of AFASA members during research) between May and June of 2009 a structured questionnaire Survey type was applied, holding 193 questions, which were analyzed using statistical software SPSS (Statistical Package for the Social Sciences). The questionnaire was splitted into two parts, the first with 35 questions: the description of coffee producer and his property. The second part with 158 questions: using a three-point answers scale, the BPAGs were listed, whose answers regarding adjustments could be: yes, partially or not, and still «not applicable». Variables found within the answer «not applicable» (in more than 50% properties), were excluded after analysis. About 70% are properties family-based, and most of them (60%) producing only coffee, the properties average size varies between 0.5 to 9 ha. Over 90% of coffee producers have been producing for over eight years and have been dedicating most of their work efforts to the coffee culture. About 80% have family monthly income below four brazilian minimum wages and more than 80% of the families survive only from agriculture. About 90% of plantations are less than 12 years-old, and only 12% produce more than two hundred bags average annual, inspite the constants coffee plantation renewals. Coffee harvest is held in cloth in more than 97% and has paved yard, either concrete or mud asphalt. Over 75% of producers commercialize their coffee through brokers from government of the municipality, and 57% of them seek weekly coffee price informations, being TV and brokers the most consulted sources. Regarding BPAGs, properties presented heterogeneous profile, and by Cluster analysis, were divided into two different groups regarding to practices and processes adopted. Crossed analyzes and discriminant were performed with the objective to select the most significant differences considered for the groups division. Fourteen practices were identified as being the most distinguished the groups profile. Group 1 was formed with 11 and Group 2 with 17 coffee producers. The conclusion was that the properties from AFASA's Associates that belongs Group 2 show better performance related to BPAGs (Good Agricultural Practices and Management), the technical assistance and rural extension should therefore continue differently between the groups.

PA 253

MODIFICATION OF FOUR-ARM OLFACTOMETERS TO BE USED  
WITH THE COFFEE BORER *HYPOTHENEMUS HAMPEI FERRARI*  
(COLEOPTERA: CURCULIONIDAE).

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The coffee berry borer, *Hypothenemus hampei* is considered to be a major pest on coffee producing countries worldwide. As in many insects, the behavior of the coffee borer is modified through aromatic signals. This has triggered important research within the different approaches of olfactometry. Two new innovative designs of olfactometers were evaluated to be used on *H. hampei* for this research. The olfactometers were built of glass and differ on the angular distribution of their arms and on the insect's inlet and adaptation zone. A mixture of methanol-ethanol 3:1, with proven attraction properties, was used to evaluate the functionality of these olfactometers. The bioassays were performed using only adult females of *H. hampei*. On the 90° olfactometer a 45% of the insects were strongly attracted to the arm comprised of the alcohol mixture. In the case of the 30° olfactometer the positive behavior response was just of a 1.5%. During the assays it was observed that the different insect insertion strategies on the adaptation camera device had a major influence on results. During the second stage of this research, the 90° olfactometer was evaluated through a comparison of average of attraction from each of the four arms of the olfactometer. There were no differences ( $p \leq 0.05$ ) in the behavioral response of *H. hampei* between each arm of the device. It is concluded that the 90° olfactometer design is suitable to develop volatile compound attraction assays on adult females of *H. hampei*.

## PA 254

 COFFEE YIELD VARIATIONS AND THEIR RELATIONS  
TO RAINFALL EVENTS IN NICARAGUA

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In order to predict the impacts of foreseen climate change on coffee production, one first step would be to check the impacts of past climate variations on coffee yields. Data on climate variables are relatively available, although sometimes of questionable quality; however, historical data on coffee yields and management are much more difficult to obtain. We developed a survey in coffee zones in Nicaragua to compile the historical registers made by farmers on yields, management and blossoming date, and analyze their relationship to specific climate events. The farmers' perceptions on climate risks and actual damages were also investigated. A simple model was then developed, that links coffee phenology, rainfall effects on flowering and soil water balance. Coffee yield data were obtained from 23 farms, over a span ranging from 6 to 78 years. The Pacific Zone, and the most ancient coffee zone, presented the longest series. Coffee yields are much more variable in this region than in the North Zone (variation coefficient 33% vs. 18%, resp.). Farmers' perceptions agreed with this finding, with much higher risks perceived in the Pacific Zone. Drought and rainfall excess alike were identified as causing the highest risks, temperature variations were not reported, possibly because they are much less easy to perceive than rainfall variations. The blossoming period was perceived, in both regions, as the most sensitive period, particularly to rainfall excess.

Very long series on blossoming dates and intensities allowed us to build and calibrate a model, based on rainfall and temperature, to estimate the rainfall during blossoming and the resulting yield loss. Rainfall over 40 mm during the blossoming could reduce the yield from 60 % (Figure 1). The water stress indexes during the different phonological stages did not show any effect in relation to coffee yields, even in the Pacific Zone that suffers from a 6 months-long dry season and high temperatures. Some alternative practices are discussed in order to mitigate the risks identified in the risk-prone Pacific zone.

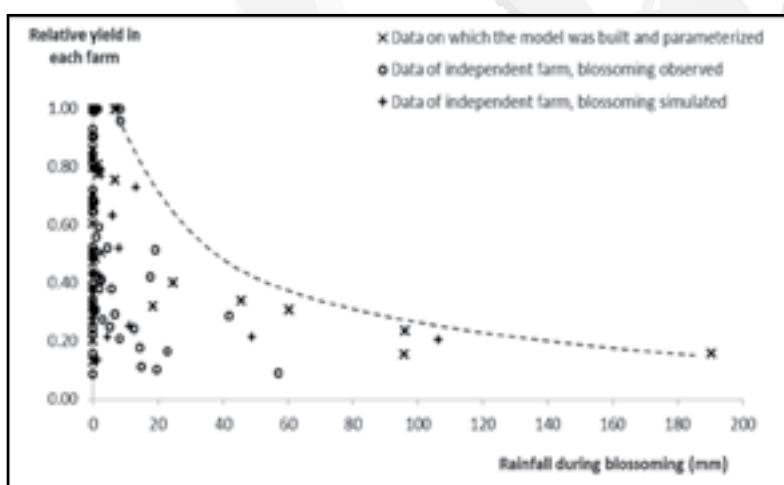


Figure 1. Relation between rainfall on flowering and coffee yield.

PA 255

ENVIRONMENTAL CHARACTERIZATION OF COFFEE IN AN AREA  
OF ENVIRONMENTAL PROTECTION IN COQUEIRAL, SOUTHERN  
REGION OF MINAS GERAIS STATE, BRAZIL

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Our recent history has been characterized by big technological, social, economic and, chiefly, environmental changes. One of the factors that influences these agroecological alterations in Minas Gerais State is coffee cultivation, due to the fact that it represents a dynamic and increasing culture. Planning for the sustainable use of natural resources requires knowledge and the organization of updated information about the environment in question. The base for any environmental study is the physiographic characterization of a region. Integrated analysis of the characteristics of a physical environment and the socioeconomic aspects of areas occupied by coffee crops allows identification of the environmental and cultural factors that facilitate coffee production. Thus, Geotechnologies play an important role for the representation and detailing of physical territories, and they are indispensable tools for conservation and management of land usage and occupation. The aim of this work was to use Geotechnologies to carry out the environmental characterization of coffee crops in an Area of Environmental Preservation (APA) in Coqueiral. In order to collect information on land usage and occupation, we used images from satellite SPOT – SPOTMaps products – with a resolution of 2.5m. Topographic charts from IBGE and the SRTM\_NASA were used to generate maps of the physical territory. The land usage map was crossed with information on the physical environment, using Spatial Language for Algebraic Geoprocessing (LEGAL) from SPRING. Coffee crops in APA Coqueiral occupy 12% percent of the total area. The majority of APA Coqueiral's surface (around 80%) is at an altitude of 734 to 900 meters above sea level. The most elevated altitudes (900 to 1040m) correspond to 20% of the area. Around 83% of coffee crops are at altitudes ranging from 800 to 950m, while 10% of coffee is at altitudes ranging from 950 to 1000 meters. 1% of coffee crops exist at altitudes superior to 1000m. Regarding crop distribution by relief class, 64.08% was on undulating (8-20%) and 23.05% was on gently undulating relief ((3-8%). Under classes of plain and heavily undulated reliefs, the coffee percentage was 3.71% and 8.96% respectively. Mountainous and steep relief showed no coffee crops. Results showed that, in the distribution of coffee crops by relief class, there was a predominance of occurrence in Argisols and Cambisols which made up around 85% of total area. Furthermore, the Gleysol/Organosol class had 8% of occupation by coffee crops, while the Litholic Neosol class showed an area of 5.05% coffee crops. The classes of soil with the lowest coffee crop occupation rate were Fluvic Neosol and rocky outcrops with 2.8% and 0.2%, respectively. Monitoring of coffee crops in this region is important, since this information provides the necessary information for maintaining a competitive and sustainable coffee sector. Therefore, environmental characterization can be considered fundamental to start the elaboration of a sustainable management plan for the area.

**PA 256****AGRONOMIC EVALUATION OF PROGENIES DERIVED FROM GENETICALLY LOW CAFFEINE ARABICA COFFEE GENOTYPES**

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Arabica cultivars presenting genetically low caffeine in beans are not yet available for commercial plantation. These cultivars will represent an important alternative for production of low caffeine coffee beans, as in addition to a differentiated cup quality, they attend the demands of consumers sensitive to this alkaloid, and, at the same time allow coffee producers to increase their income due to the possibility of adding value to the final product. This study aimed to identify plants that combine appropriate levels of productivity, high cup quality and beans with low levels of caffeine. Plants from F<sub>2</sub> and F<sub>1</sub>BC<sub>1</sub> generations of crosses involving low caffeine mutants and commercial cultivars, along with clonal varieties developed from mutant AC plants, were evaluated during 2010/2011 crop year. Agronomic aspects such as production, vegetative vigor, maturity cycle and reaction response to coffee leaf rust and die-back were evaluated, as well as determination of caffeine content in the beans. In general the progenies with the best behavior comparing to the average production were those originated from backcrosses. Among the F<sub>2</sub> progenies two had average production similar to the controls IAC 81, IAC 144 and IAC Ouro Verde. Also, plants with low caffeine content were observed among a F<sub>2</sub> progeny, but a higher frequency of low-caffeine plants was observed in backcrosses progenies. As expected clonal plants from the low caffeine mutant genotype, and as well as some descendent progenies showed low levels of caffeine in beans, less than 0,1%. These results indicate the possibility of either utilization of these genotypes in the development of new low caffeine clonal cultivars or carry-on with the breeding program to develop seed propagated cultivars.

**PA 257****BANANAS IN COFFEE PRODUCTION SYSTEMS IN LATIN AMERICA: ASSESSING AGROECOLOGICAL AND SOCIO-ECONOMIC BENEFITS**

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Bananas are commonly grown by small coffee growers in shaded coffee fields throughout Latin America, occupying over a half million hectares in Mesoamerica, the Caribbean and South America. Coffee technicians, focusing on coffee modernization, advice small coffee growers to eliminate bananas from their coffee fields, proposing that bananas generate excess shade, compete for nutrients and water, increase nematode problems for coffee, and cause damage to coffee bushes during banana harvest. We analyzed the results from our grant focused on small farmer strategies to improve the productivity and value of banana in shaded coffee to assess the agroecological and socioeconomic costs and benefits of bananas in this system. In seven sites in Honduras, Nicaragua, Costa Rica and Peru we surveyed 30 shaded coffee plots with banana in each country to characterize coffee, banana and tree density and estimate light partitioning. In meetings with farmer experimentation groups during 2010-2012, we collected and analyzed data on labor and input costs and income with farmers. Studies were also conducted on the effects of the presence of banana on nematodes, ants and earthworms in selected sites. Four questions guided our analysis. Does the presence of banana reduce the availability of light, nutrients and water for coffee below crop requirements? Does banana increase soil pest problems for coffee? Do bananas increase labor costs for coffee production? Does labor invested in banana provide better returns than if the same labor were invested in coffee? Light reaching coffee in these multi-strata systems was generally below 50%, averaging between 29 and 49% in the different zones. Visual estimates suggested that banana intercepted between 11 and 32% of total light for 6 zones

with one zone at 50% interception. Light interception by the tree strata was much more variable between 16 and 53%. Calculations of nutrient export in banana and coffee indicated that most farmers had a positive balance for nitrogen, but were negative for potassium. Potassium exported in 300 20kg bunches of banana was equal to potassium in 22 hundredweights of green coffee. Studies on water use were not conducted, but banana is a water conserving crop. Stomata close when soil water drops to -0.10 to -0.20MPa, well above levels for coffee at -0.50 to -1.0MPa. A comparison of nematode communities in coffee, banana and trees in different combinations found significantly higher levels of predator nematodes with the presence of banana which led to lower plant parasitic nematodes in coffee with banana. Plots with banana also had higher levels of ground cover litter. The banana component absorbs between 15-40 work days/hectare (approximately 12% of total production costs/ha), primarily for deleafing and desuckering (52-66%). These agronomic practices are done primarily during weeding, which increases the total weeding cost. However, farmers suggested that the presence of bananas reduced weeding costs in coffee due both to increased ground cover from banana residues and the easily managed shade. Gross income from bananas ranged from \$USD200-450, about \$10-12 gross return per day of labor, or the value of 1-3 hundredweights of green coffee. Given the flexible labor scheduling of banana management throughout the year, the shifting labor from banana to coffee may not compensate the loss of banana income with increased coffee-yields. In addition, the income from banana is monthly, taking on a greater importance, according to farmers when coffee income has run out, 3-4 months after the harvest.

**PA 258**

### **EXTRAFLORAL NECTARIES OF INGA TREES ENHANCE NATURAL CONTROL OF COFFEE PESTS\***

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Simplification of agricultural landscapes leads to deterioration of ecosystem services, such as natural pest control. Increasing plant diversity can increase natural enemy populations, for example because plants provide alternative food to natural enemies. Extrafloral nectar is such an alternative food, and can increase the number of natural enemies, resulting in less herbivory on plants bearing extrafloral nectaries. However, little is known about the effect of extrafloral nectary plants on herbivory of associated plants. Coffee agroforestry systems usually contain trees bearing extrafloral nectaries, *Inga* spp. (Leguminosae) being one of the most common. We assessed the effect of nectar availability from inga trees on parasitism of coffee leaf-miners (*Leucoptera coffeella*) and on damage caused by leaf miners and coffee berry borers (*Hypothenemus hampei*) in five coffee agroforestry systems in the municipality of Araponga, Minas Gerais, Brazil. From each system, five inga trees (*Inga subnuda* subsp. *luschnathiana*) were sampled. Abundance and richness of nectar feeding insects were used as an indirect measurement of nectar availability. Nectary visitors were counted and identified, and mined leaves, leaves and fruits were collected. Samples from coffee plants were collected every meter along a transect of 10-15 m extending from each inga tree. We collected 287 visitors of 79 morphospecies on the nectaries. Parasitoids represented 16.7% of the visitors and predators 59.9%, most of them being ants (53.3%). Ants were more abundant during midday and parasitoids during the afternoon. The distance of the coffee plants from the inga trees did not significantly explain variation in coffee leaf-miner parasitism, in coffee leaf-miner damage or in bored coffee berries. However, the parasitism rate, proportion of mined leaves and the proportion of bored fruits per transect varied significantly with abundance of nectary visitors, but not with visitor species richness. Leaf miner parasitism increased significantly with the density of natural enemies. The proportion of mined leaves and of bored fruits decreased marginally significantly with increasing densities of visitors. We conclude that extrafloral nectaries of inga trees provide alternative food to natural enemies of coffee pests, resulting in increased natural control. This could be caused by the natural enemies aggregating around the trees providing nectar and to a numerical response of natural enemy populations due to increased availability of food (nectar). Hence, diversifying coffee plantations with inga trees can be a good strategy to enhance natural pest control.

\*National Council of Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES) and Minas Gerais State Foundation for Research Aid (FAPEMIG) are thanked for financial support and fellowships for the authors.

## PA 259

## BIONUTRITION OF COFFEE PLANTS

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Fertilization is one of the most expensive activities among the agronomic practices demanded by coffee plantations, with a participation of around 14% of the total production costs. For the year 2012, the costs of fertilization/ha/year for a coffee plot under full sunlight condition planted at a density of 6.000 plants/ha were around US 849. This elevated price tag created the necessity to explore alternatives for either diminishing these costs or maintaining them but under an improved environmental sustainability strategy. Within the plant growth promoting Rhizobacteria (PGPR), there is a group with the capacity to fix nitrogen, to increase the availability of nutrients for the plants, and to detoxify soil, contributing to plant health and higher yields. Since 2002, a biofertilization study of coffee plants was carried out in Cenicafé evaluating the biological product Bacthon® (*Azospirillum brasiliense*, *Azotobacter chroococcum*, *Lactobacillus acidophilus* and the *Saccharomyces cerevisiae*) in combination with different doses of a simple chemical fertilizer made up with Urea, Potassium Chloride and Diammonium Phosphate, as defined by these groups: Group 1: Chemical fertilization alone; Group 2: Reduction between 25% and 50% of chemical fertilizer + one application of the biological fertilizer/year; Group 3: Reduction from 75% of chemical fertilizer + two applications of the biological fertilizer/year; Group 4: Biological fertilizer alone. All treatments were applied three times a year (March, July and November). The variables evaluated for each treatment during the first productive cycle of the coffee plants (2002-2006) were growth, Iron Spot incidence on leaves and fruits, and yield. Results indicated that coffee plants treated with chemical nutrients reduced to 178 Kg/ha/year of N, 74 Kg/ha/year of P<sub>2</sub>O<sub>5</sub> and 194 Kg/ha/year of K<sub>2</sub>O (for a total of 446 Kg/ha/year) combined with one application of the biological fertilizer (1,5 L/ha/year), showed the largest growth reflected in plant height and number of crossings on the stem. Statistically, these plants also presented the lowest Iron Spot incidence and the greatest yield when compared to coffee plants that received higher or lower doses of chemical fertilizer. For the first productive cycle and under the environmental conditions in which the experiment was carried out it was possible to reduce the dose of chemical fertilizer without affecting growth, development and production of coffee plants.

Fulfilled the first productive cycle, coffee plants were renovated by stumping (march/07) and the experiment continued for a second productive cycle using the same treatments, variables and evaluations. Data for the second cycle (fourth year-2011) are showing that the dose of chemical fertilizer can be reduced even more without affecting the development of the plot. Coffee plants treated with the dose of chemical nutrients corresponding to 118 Kg/ha/year of N, 50 Kg/ha/year of P<sub>2</sub>O<sub>5</sub> and 130 Kg/ha/year of K<sub>2</sub>O (298 Kg/ha/year) in alternation with the biological product (1,5 L/ha/year) are displaying the largest growth, lowest Iron Spot incidence in the cherries and highest yield. This result, still with one year of experiment before concluding, indicates that it is feasible to restore, protect and improve the soil physical, chemical and biological conditions to benefit the amount and quality of the coffee berries and at the same time preserve the sustainability of coffee plantations.

## PA 260

## IMITATION OF HIGH QUALITY COFFEE NICHES IN NICARAGUA TO IDENTIFY THE POTENTIAL FOR DENOMINATION OF ORIGIN

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The registration process for protected denomination of origin is very demanding in terms of organizational and technical capacity. Technical studies require a detailed description of the products, maps delineating the zone and the associated criteria defining this delineation. Further it requires a description of the production processes and details on the elements which are directly affecting the quality of the products. It needs a description of the control and traceability mechanisms to ensure the fulfillment of the requirements and the analysis or studies that certify the link between the products and territory. Finally, a normative of use and administration for geographical indications (GI) or origin denominations (OD) needs to be defined. The studies have to answer three questions for OD: (1) Is the quality unique? (2) Is the niche unique?; And (3), is there a link between niche and quality?. If all three answers are "Yes", then the niche can qualify for OD.

The present study was conducted in the Nicaraguan coffee zone, where data of geographic coordinates of producers were collected by GPS and cupping data following the Specialty Coffee Association of America (SCAA) standard for sensorial attributes was evaluated through various institutions. The data was analyzed with different environmental layers (e.g. precipitation, mean annual temperature, daily temperature range, dew point, consecutive dry months, solar radiation, and elevation) in a GIS model. Based on these data, spatial and statistical analysis was conducted in order to demonstrate the interaction between quality and environment. Spatial analysis was done using the Bayesian statistics based Crop Niche Selection for Tropical Agriculture. The statistical analysis was done using descriptive statistics to determine the quality of the data and by conducting a cluster analysis to group the sample sites.

At least five potential niches for producing high quality coffee were identified: Dipilto (Dipilto, Macuelizo and Mozonte), Las Sabanas (Las Sabanas, San Lucas, Pueblo Nuevo), San Juan del Rio Coco (San Juan del Rio Coco, Telpaneca) Jinotega (Jinotega, Datanli, el Diablo, Peñas Blancas) and San Rafael del Norte (San Rafael de Norte and San Sebastián de Yalí).

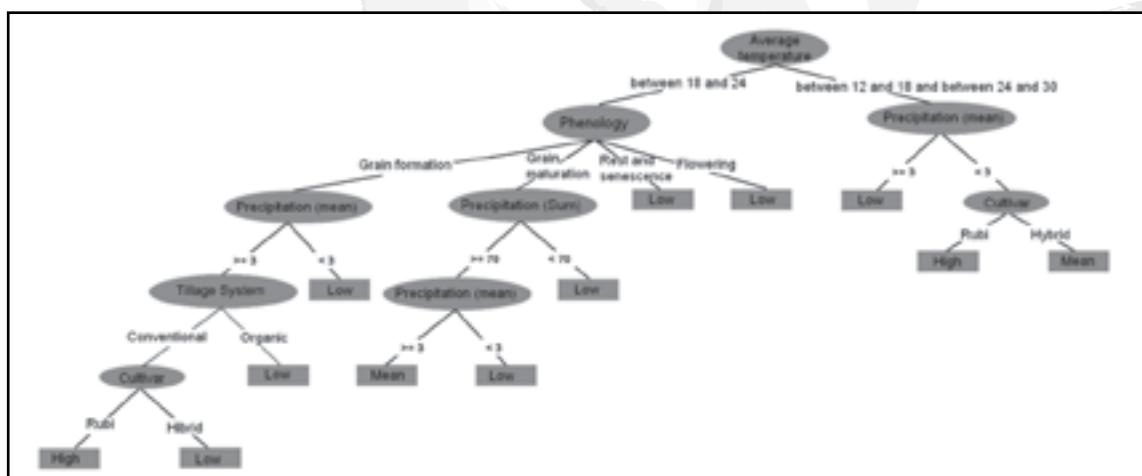
The results show that cupping data consistency is essential for niche-modeling and that the environmental conditions significantly influence coffee quality and therefore enable the mapping of the attributes. The spatial probability analysis confirms that there is a high potential to produce high quality coffee at the identified sites. The differences in coffee quality are not random but show a clear spatial distribution, illustrating the relation between the environmental variables and the coffee quality according to coffee cupping profile.

**PA 261**
**APPLIED DATA MINING TO MODELING THE OCCURRENCE OF BROWN EYE SPOT (*Cercospora coffeicola* Berkeley & Cooke) COFFEE TREE**

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Cercospora leaf spot is one of the oldest diseases of coffee, caused by *Cercospora coffeicola* Berk & Cook. The disease is widely disseminated in all Brazilian coffee regions, causing damage both in arboretum and in the field, in young plants and adult, attacking leaves and fruits. Despite the importance of Cercospora leaf spot, little is known about its causal agent. Determinations of environmental conditions that favor the disease are generic, such as high relative humidity, temperature between 10 and 25°C, excess sunlight and water deficit. So, the study of the progress of cercospora leaf spot becomes potentially useful and required in the understanding of disease and in the process of decision making for control measures. Associated with this, computer programs assist to elucidate biotic or abiotic factors, which are more representative. Thus, the objective of this study was to investigate by using the data mining techniques to discover the phenological and environmental attributes that most influence the occurrence of Cercospora leaf spot on coffee trees in southern Minas Gerais state - Brazil, under two different tillage systems: conventional and organic. To this end, we organized data on the incidence of Cercospora leaf spot in two cropping systems, to climatic factors and phenology of culture, in a period of five years of evaluation. Then we used a specific software to get the attributes of the higher separability of the occurrence of Cercospora leaf spot. The models generated were 60% hit rate and showed that the average temperature was the highest attribute of separability in all of the data and the conventional system of cultivation. Organic management in monthly rainfall and phenology influence the occurrence of the disease. The model (decision tree) for the occurrence of cercospora systems in conventional and organic production can be viewed in Figure 1.



**Figure 1:** Model (decision tree) for the occurrence of cercospora systems in conventional and organic production.

**PA 262**

**YIELD RESPONSE OF SELECTED NEW *Coffea arabica* VARIETIES GROWN UNDER SHADED AND UNSHADED PRODUCTION SYSTEMS**

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A pilot study was conducted at Lyamungu, Tanzania from 2007-08 to 2010-11 seasons to assess the response of 4 selected new varieties when grown under shaded or unshaded condition. Two blocks were selected adjacent to each other. The first had a sparse, pre-established shade of *Albizia* trees while the second was unshaded. In each block, a separate variety performance trial was established in a Randomized Complete Block Design (5 varieties N39-2, N39-4, N39-5 and N39-7 with KP423 commercial variety as a check, replicated 4 times). Yield data in kg of clean coffee per ha were subjected to descriptive statistics and analysis of variance under COSTAT Software. The comparison of varieties across the seasons showed the check variety KP423 as least affected by biennial bearing, with a steady increase in mean yields. The second was N39-5 which suffered a decrease in 2008/09 followed by a steady increase. N39-4 showed very little decrease between 2009/10 and 2010/11, while a typical biennial bearing was noted with N39-2 and N39-7. In terms of variability, replications and seasons were highly significant ( $p<0.01$ ) while seasons x varieties were significant ( $p<0.05$ ). Varieties alone were not significant ( $p>0.05$ ), implying that biennial bearing is not related to varieties but rather the environment in which they grow and the way they are managed. The overall results showed biennial bearing with the highs in 2007/08 and 2009/10; and lows in 2008/09 and 2010/11, though their differences were not significant. Variety N39-4 showed the least variation in yield between the shaded and unshaded systems with highest mean yield of 901 kg clean coffee per ha; while N39-7 had the lowest yield of 656 kg.ha<sup>-1</sup>. Other varieties which did not differ significantly among themselves were N39-2, KP423 (check) and N39-5 with mean yields of 838, 796 and 782 kg.ha<sup>-1</sup> respectively. Mean yields in the unshaded system were about two times those under shade. The results seem to rule out varieties as a factor in the problem, which opens up avenue for research on other factors such as climate, crop husbandry practices and the policy environment.

**Key words:** Yield response, biennial bearing, production systems

**PA 263**

**EFFICACY OF FISH BEAN, *Tephrosia vogelii* FOR THE MANAGEMENT OF COFFEE ANTESTIA BUGS, *Antestiopsis spp* IN KILIMANJARO REGION, TANZANIA**

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The efficacy of Fish bean, *Tephrosia vogelii* against Antestia bugs, *Antestiopsis* was evaluated in the laboratory and in the field from February, 2011 to August 2011 at Tanzania Coffee Research Institute (TaCRI). A bioassay and field experiment at 4 dosages of Fish bean extracts, Profenofos 720g/l (Selecron 720 EC) (standard) and untreated (control) were used in Complete Randomized Design (CRD) and Complete Randomized Block Design (CRBD), with 6 replications. Fresh leaves of fish bean (800, 1000, 1200 and 1400 gram) were collected in the field before flowering and grinded in a mortar with a pestle and one litre of water was made and left for 24 hours. The mixture was filtered using a clean cloth. The formulation obtained was mixed with 10 gram of soap. A total of 720 adult Antestia bugs were collected from the field and 20 Antestia bugs were put in each Petri dish having 20 green berries to feed. Four dosages (800g/l, 1000g/l, 1200g/l and 1400g/l) of leaves extract of the plant, Selecron 720 EC 1.5 milligram/litre of water and untreated (control) were applied to 20 Antestia bugs

contained in each Petri dishes using one litre of atomizer, later placed in a temperature and relative humidity control machine. On the other hand the same treatments were tested in the coffee tree under field conditions. In the field experiment the same 20 bugs were put in a mosquito net slid over coffee branches and tied at the ends with sisal twine to prevent the bugs from escaping. The mortality rate of pest in both laboratory and field experiment was recorded at 24, 48 and 72 hrs. Results showed that there were no significance differences ( $p \leq 0.05$ ) of fish bean extract at 1200g and 1400g as compared to the standard (Selecron 720 EC) in both the laboratory and field trials at 72 h in mortality rate of the pest. However, significance differences ( $p \leq 0.05$ ) were observed between fish bean extracts at 800g and 1000g/litre of water and the standard (Selecron 720 EC) in both laboratory and field experiments for mortality rate of the pest. The Fish bean rate at 1200g/litre does not differ significantly ( $p \leq 0.05$ ) with the standard (Selecron 720 EC) is recommended to be used by our coffee farmers for management of Antestia bugs at the medium altitude (1200 - 1600 m a.s.l.). The results are discussed also with regard to the use of botanicals by small scale coffee farmers as a cost effective and suitable alternatives to synthetic insecticides. Further research to evaluate the efficacy of Fish bean in different altitudes for management of the pests is underway.

*Key words:* botanicals, synthetic insecticides, *Antestiopsis spp*, *Tephrosiavogelii*, small scale farmers

## PA 264

### DISSEMINATION STRATEGIES OF TECHNOLOGIES TO COFFEE GROWERS IN TANZANIA

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Coffee is one of Tanzania's primary agricultural export crop produced 90% by smallholders and 10% large producers. The industry provides direct income to more than four hundred thousand farmer families and also benefits indirectly the livelihoods of over two and half million Tanzanians. Despite all the benefits obtained from coffee, production levels have been below the potential. To address the existing problem of low production levels, the Tanzania Coffee Research Institute (TaCRI) has packaged and is currently promoting and disseminating appropriate technologies to coffee growers together with empowering coffee growers with sustainable technologies. This has been successful done by conducting promotional activities including provision of village based training. Over the last ten years, about 268,935 coffee growers across the country have benefited from the training with over 962 demonstration plots established on farm; 140,215 extension materials distributed to coffee growers and 89 open days conducted in coffee growing areas. The results show that there is increase in the number of coffee growers who adopt the new technologies, increased the area planted with hybrid varieties, increased coffee yield and improvement in the livelihoods of coffee growers. Therefore, this paper outlines various strategies that TaCRI and coffee growers have been implementing to rejuvenate the coffee industry in Tanzania.

*Key words:* Dissemination strategies, appropriate technologies, coffee growers, Tanzania

**PA 265**

## OYSTER MUSHROOM FARMING UTILIZING PRIMARY COFFEE WASTES: PRELIMINARY RESULTS FROM NORTHERN TANZANIA

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Coffee farmers in Tanzania are producing over 200,000 of tones of coffee wastes from their farms annually. These coffee wastes includes coffee pulps and coffee husks which are commonly left to decay on top of the soil, disposed in rivers, streams or burnt ending up polluting the environment. Primary wastes from coffee farms can be economically spent by growing oyster mushrooms which in turn provides a complimentary source of income to cushion the effect of fluctuating coffee prices in bad years as well as giving coffee farmers the capacity of purchasing some of the necessary inputs and equipments required to maintain their coffee farms. The study showed that on average a small scale farmer produces 100 kilograms of wastes per year which has a potential of producing 120 kg of fresh mushroom (oyster). The average price for a kilo of fresh mushroom (oyster) in local supermarkets and hotels around the study area is USD 4 gives a farmer a total of USD 480 per season from 100 kg of wastes produced. The harvested mushrooms are also used by the coffee farmers themselves as an important source of protein thus improving their health. After harvesting mushroom, the spent mushroom substrates (SMS) can be used as organic fertilizers as it contains 1.70% N, 0.61% P<sub>2</sub>O<sub>5</sub> and 1.13% K<sub>2</sub>O. Thus, with mushroom farming technology using primary coffee wastes, coffee farmers can complement their coffee income to improve their food security and livelihoods.

*Key words:* Oyster mushroom, coffee farmers, coffee wastes, Northern Tanzania

**PA 266**

## FACTORS AFFECTING THE VEGETATIVE MULTIPLICATION OF IMPROVED COFFEE SEEDLINGS BY FARMER GROUPS: A CASE STUDY OF NORTHERN TANZANIA

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Tanzania coffee research institute (TaCRI) is working with more than 800 small holder farmer groups. The groups have more than 300,000 mother plants which are used as source of cutting for hybrid seedlings multiplication. Out of this, Northern coffee growing zone have 251 farmer groups with 83, 171 mother plants which are used as source of cutting for hybrid seedlings multiplication. If used efficiently, the mother seedlings have potential of producing 2,094,275 hybrids seedlings per year. This amount of seedlings can replace about 1,600 hectares of traditional disease susceptible varieties per year. Data collected using questionnaires and analyzed SPSS statistical packages shows that 20% of the seedlings have been produced by TaCRI, 15% by estates, 6% by cooperative, 4% by district nurseries, 1% of individual farmers and 54% by farmer groups. This shows the importance of the farmer groups in seedlings multiplication process. Information from questionnaires also revealed that involvements of women, strong leaderships, trainings on running vegetative propagation units (VPUs), frequently backstopping of farmer groups, and prices of seedlings at or above breakeven point (approximately US \$ 0.8 per seedling), availability of media forest soil, land for establishment of nurseries and VPU, positively facilitate seedlings multiplication process. This report highlights some factors affecting seedlings multiplication in the Northern zone, and suggests ways for improvement to increase the rate of multiplication per cycle.

*Key words:* Multiplication, Improved Varieties, Farmer groups

## PA 267

INFLUENCE OF CLIMATE CHANGE ON COFFEE YIELD  
AND PRODUCTION IN EAST AFRICA: 1961-2009**CRAPARO, Alessandro, C.W.**

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Coffee has a global value of approximately US\$100 billion. It contributes significantly to developing countries GDP's and supports the livelihoods of millions of people, especially in the equatorial regions of East Africa. However, *Coffea arabica* is highly sensitive to climate change, with a particular vulnerability to changes in temperature and precipitation. As a result of the lack of availability and quality of data from the region, few studies have considered the degree to which climate variables have influenced the past trends in green coffee yields and production. Using regression analysis and Neural Networks, the relationships are presented for Ethiopia, Kenya and Uganda. Data from the FAO Climpag and FAOSTAT databases for the period 1961 – 2009 are used for the analysis. Temperature is the most significant climate variable responsible for the trends in coffee yield (Hg/Ha) as well as production (T) in the region. More specifically, the minimum temperatures for each country are the most influential, with the greatest correlations to yield rather than production. With a one degree rise in the mean temperature, there is generally an average loss of 116 Kg/Ha of green coffee in each country. Whereas, a one degree rise in the average minimum temperature is associated with an average increase of 136 kg/Ha in Ethiopia and a relatively small loss of 61 Kg/Ha in Kenya. While rainfall is not as influential as temperature, it is proposed that the two act synergistically to drive coffee yield and production in the East Africa region. These three variables account for approximately two thirds of the variation in green coffee yield and production, while other environmental, social, political and economic factors are proposed to be responsible for the remainder of variation. This analysis is part I, with part II considering the plant-climate relationship at a higher resolution farm-scale level.

## PA 268

LANDUSE COMPOSITION AND CONFIGURATION AFFECT  
COFFEE BERRY BORER DISTRIBUTION AND DISPERSAL  
IN LOCALIZED FARMSCAPES**DECLERCK, Fabrice<sup>1,2</sup>, AVELINO, Jacques<sup>2,3,4</sup>, RIVERA, Cipriano<sup>2</sup>, OLIVAS, Amada<sup>2</sup>**

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The coffee berry borer (*Hypothenemus hampei*) is a major pest of coffee in Central America. Recent studies demonstrate landscape context impacts distribution and dispersal of this pest where probability of successful dispersal events is higher across some agricultural land uses such as sugar cane and pasture, but limited by others, in particular forest. This impact of land use composition has been tested at local (Olivas et al. 2011), and landscape scales (Avelino et al. 2012). In this study, we used a small mixed-use landscape (550 x 550 m; 30.25 ha) to further test the impact of land use composition and arrangement on coffee borer densities and distribution. We placed 121 ethanol-based coffee borer traps (Brocap ®) at 50 m intervals throughout the sample grid plus an additional 32 traps located 10 m from adjacent traps along both diagonals of the study area for a total of 153 traps. We checked these traps every two weeks during a five-month period between February 2<sup>nd</sup> and July 7<sup>th</sup> 2010. Traps were located in eight different land uses, including: coffee (22%), pastures (22%); sugar cane field (18%), banana orchard (16%); pine plantation (10%), forest (9%); and annual crops (3%). Coffee dominated the SW, SE, and NE corners of the grid, but was intersected by the other land uses. The forest formed a "T", with a ridgeline forest transecting the plot from west to east across the center, and a narrow (40 m) riparian forest bisecting the lower half of the plot from north to south. We captured a total of 9984 dispersing female beetles, with the peak capture during the last two weeks of February. The majority of the coffee borers were found in the coffee plots as expected (64%). Thirty-six percent were found outside of coffee. The presence of coffee borers was significantly different in the alternate land uses with the

lowest densities in the forest (3%). Densities by trap were higher in alternate land uses as follows: sugar cane (6%); pasture (10%); pine plantation (12%); annual crops (13%); and banana plantation (55%). Krigging of the points showed strong spatial significant with the highest degree of semivariance running perpendicular to the forest patches, and the lowest, running parallel suggesting a strong influence of the forest elements in directing beetle distributions. We further conducted correlations between the proportions of each land use at 5-200 m intervals of radius to test the effects of local spatial context on beetle densities within the coffee points. Our results demonstrate that management of local landscape context can influence the control and management of the coffee boring beetle by limiting the movement of the organism and either increasing the effectiveness of field scale management intervention and/or reducing re-infestation rates.

Avelino et al. (2012). Landscape context and scale differentially impact coffee leaf rust, coffee berry borer and coffee root-knot nematodes. *Ecological Applications*. 22(2):584-596.

Olivas, A. 2010. Efecto del uso del suelo adyacente al cafetal sobre la dispersión y dinámica poblacional de la broca Hypothemus hampei Ferrari y la abundancia de enemigos naturales en el cantón de Turrialba, Costa Rica. CATIE Master's Thesis. Turrialba, Costa Rica.

**PA 269****ECONOMIC ANALYSIS OF THE CERTIFIED COFFEE PRODUCTION IN NICARAGUA**

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The certification of the coffee production has between its objectives providing better price and a stable market to the coffee producers and to improve of this way their incomes. But really they fulfill the certifications with these objectives? Considering that Central America and Mexico is the region most important at worldwide level for the production of washed arabic coffee and also the most important in the production of certified coffee, this study was developed at the national level in Nicaragua, 294 surveys were applied to coffee growers in according with the size of the coffee farm and location. The certifications sampled were Rain Forest Alliance (RFA), C.A.F.E. Practices (SCP), Fair Trade (FLO), UTZ certified (UTZ), organic (ORG) and conventional (CONV). Economic, social and environmental data were collected. In the economic analysis, we reviewed labor costs (family and hired), fertilizer costs and total costs of production. Also we analyzed the productivity, price and income among others variables.

The preliminary statistical results show that the family labor costs are higher in CONV (\$271 usd ha<sup>-1</sup>), FLO (\$239 usd ha<sup>-1</sup>), ORG (\$235 usd ha<sup>-1</sup>) and UTZ (\$222 usd ha<sup>-1</sup>), while the lowest was in SCP (\$77 usd ha<sup>-1</sup>). In the hired labor costs, these were higher in SCP (\$663 usd ha<sup>-1</sup>) and the lowest were in UTZ (\$361 usd ha<sup>-1</sup>), and ORG (\$412 usd ha<sup>-1</sup>). In costs of fertilization the higher was SCP (\$515 usd ha<sup>-1</sup>) and the lowest was UTZ (\$80 usd ha<sup>-1</sup>) and ORG (\$111 usd ha<sup>-1</sup>). In the total costs of production per quintal the higher was ORG (\$101 usd qq<sup>-1</sup>) and the lowest were SCP and RFA with (\$61 usd qq<sup>-1</sup>).

The profitability is higher in the private certifications RFA (\$1334 usd ha<sup>-1</sup>) and SCP (\$1713 usd ha<sup>-1</sup>) while the lowest was in UTZ (\$430 usd ha<sup>-1</sup>), CONV (\$703 usd ha<sup>-1</sup>), ORG (\$808 usd ha<sup>-1</sup>) and FLO (\$892 usd ha<sup>-1</sup>), these result are directly related to productivity since this was lower in ORG (13 qq ha<sup>-1</sup>) and UTZ (12 qq ha<sup>-1</sup>) while in SCP was highest (26 qq ha<sup>-1</sup>). About the price, ORG (\$130 usd qq<sup>-1</sup>) and RFA (\$131 usd qq<sup>-1</sup>) received the best price, while UTZ (\$95 usd qq<sup>-1</sup>) showed the lowest selling price.

We conclude that the productivity is the factor that most affects the profitability of the certifications such as ORG, since despite having a good price is less profitable. In a deeper analysis we must to consider other social and environmental characteristics that can establish important differences between the certifications analyzed.

## PA 270

BREEDING A DWARF TYPE COMPOSITE VARIETY ON ARABICA COFFEE RESISTANT TO LEAF RUST (*Hemileia vastatrix*)**HULUPI, Retno , MAWARDI, Surip and NUGROHO, Dwi**

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In order to obtain a durable resistant variety of Arabica coffee to leaf rust (*Hemileia vastatrix*) through a pure line breeding approach is time consuming (over 25 years) due to requirement of recurrent selection over segregation generations. Meanwhile, development of a new race(s) of the pathogen frequently has broken down a monogenic or oligogenic based resistance of elite varieties that newly released for commercial planting. This composite variety composed by several selected elite genotypes having similar performance of morphological traits but contains different resistance genes to leaf rust, which is expected to perform an horizontal or durable resistance in a population based on polygenic action. Selection of elite individual genotypes of Arabica coffee to create a composite variety had been done at an endemic *H. vastatrix* infected area namely at Andungsari Experimental Station (1,300 m a.s.l.), East Java, Indonesia for 6 years harvesting periods. The was initiated by a trial involving 136 selected genotypes derived from sibblings of Catimor progenies bearing main resistance gene to *H. vastatrix* of SH6 originated from different areas as well as from F2 population having main resistance gene of SH3. Trial over the mentioned selected genotypes used randomized complete block design consisted of 10 plants per genotype and 3 replications, planting distance was 1.75 m within row and 3.50 m between rows. Data record was conducted over six years harvesting periods consisted of agronomic traits, yield and bean quality as well as resistance to leaf rust. Evaluation of resistance to leaf rust was done twice a year both *in vitro* (based on leaf-disc artificial inoculation) and *in situ* (based on natural infection). The resistance evaluation was based on the method developed by Eskes & Toma-Braghini (1981), Dakwa (1987) and Mawardi (1996). Cluster analysis using the NTSYST 4.6 program was applied to precise selection of elite genotypes.

Based on the cluster analysis, from 136 tested genotypes there were 6 elite selected genotypes for constructing a composite variety. The six elite genotypes performed dwarf type and similar agronomic traits as well as resistant to leaf rust in addition to have good cup quality. The composite variety also performed high yield potential namely 2.10 ton/ha at population level of 2.000 plants/ha. It is a new promising variety to release by the government for commercial planting material in Indonesia.

Keywords: Composite variety, population breeding, durable resistance, leaf rust, dwarf type.

## PA 271

## OCURRENCE OF SCALD AND COFFEE LEAF MINER ON ARABIC AND CONILON PLANTS AT SEMI-ARID CLIMATE

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Due to strong evidences of global warming, coffee plant behavior at warmer climate can point the best actions to be developed to minimize the temperature raise impacts on coffee crops. Higher temperatures can start oxidation stress at coffee plants as well as variations at population dynamics of leaf miner. This paper evaluate sunburn and leaf miner population at *Coffea arabica* (Catuai vermelho 144) and *Coffea canephora* (conilon Vitória - Incaper 8142, 13 clones) at a semi-arid region of Minas Gerais State. Randomized blocks were used with four replicates with plots made up by six plants. At end of raining season, even at higher temperatures, leaf scald was not observed on either coffee specie. At end of dry season, the sunburn incidence was 25% on both species. Leaf scald was caused mainly by longer period of insolation. Sun radiation at this period is higher than that necessary to saturate the photosynthesis dealing with light inhibition, reducing the photochemical efficiency of Photosystem II, promoting formation of reactive species of oxygen able to result

on damages such as photo-inhibitors or photo-oxidatives. At Arabic plants, leaves fell at end of dry season, caused also by high infestation of leaf miner. The Arabic plants presented 2.15 mines per leaf and 77.5% of infestation at end of raining season. As could be expected, such high infestation prolonged along the dry season reaching 100% of leaves with half of them falling from the plant. On conilon plants, infestation was 50.91% with 0.79 mines per leaf at end of raining season. At end of dry season infestation varied from 32.77% with 0.5s mines per leaf to 46.34% and 0.72 mines per leaf. Conilon plants didn't present leaf falling as Arabic ones, keeping their leaves at plants. The semiarid climate with high temperatures and low humidity might contribute to occurrence of leaf miner, turning its life cycle very short. Short cycles can result in high infestation at a short period of time. Wind can contribute to leaf miner attack promoting insect dispersion. Despite of this, higher water evaporation from leaves can also contribute to leaf miner larvae. Therefore, for both coffee species to adapt at semi-arid region, it is mandatory to control leaf miner attack, mainly on Arabic plants where leaf fall can be very intensive. At Canephora plants, although the infestations and leaf area being reduced, leaf maintenance by the plants might constitute a barrier against sunburn of coffee flower buds or

**PA 272**

### **SUSTAINABLY INCREASING PRODUCTIVITY OF COFFEE SYSTEMS IN EAST AFRICA**

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Coffee is a major cash crop in the East-African countries accounting significantly to their export revenues. Banana is a major food crop that also contributes to regional economies. Even though these crops are pillars for East-Africa, both crops are in crises due to low soil fertility, pest and disease pressure and suboptimal management conditions. Yields in the region only attain 20-30% of potential yields. Furthermore, smallholder farmers produce 90% of the coffee and these limitations affect their livelihoods deeply.

In this paper, we will present the results from two diagnostic surveys in Uganda and link these results with other studies in East Africa. The aim of these surveys was to characterize constraints and opportunities in coffee-banana smallholder systems in Uganda. During this study, 50 participatory rural appraisals (PRA) were run with approximately 50-60 coffee farmers attending and 250 coffee farmers were surveyed individually throughout Uganda. Yield parameters, biotic and abiotic constraints at plot level and socio-economic factors were either measured or asked to the farmer. In addition, a perception study was tagged on to understand perceptions of farmers on the different coffee systems existing like coffee monocropping without shade, coffee monocropping with shade trees and coffee-banana intercropping. For this perception study, 40 stakeholders (8 decision makers, 8 extension agents and 24 coffee farmers) were interviewed for 2 hours in a semi-structured way.

The major constraints identified during the survey were mapped for the whole of Uganda and will be presented. The results show a large variability in the agro-ecological and socio-economical context in which coffee farmers in Uganda live and call for site-specific interventions. Due to low soil fertility in most of Uganda, integrated soil fertility management practices will be discussed together with site-specific fertilizer recommendations calculated with compositional nutrient diagnosis (CND). Furthermore, the study showed that coffee farmers intercropping their coffee with bananas could double their income per unit area. However, due to increased competition for nutrients, water and light, this system requires good management practices in order to be sustainable.

The study also shows the opportunities and constraints of coffee systems in regards to climate change mitigation and adaptation. Including shade could make a system more resilient to drought but will require better management. Furthermore, data shows that certain recommended shade trees can be hosts for coffee pest like black twig borer and increase its incidence.

The study concludes that there are opportunities to increase productivity of coffee systems in Uganda, but they are site specific. There is no silver bullet solution but a variability of interventions that need to be adapted to specific livelihood of coffee farmer.

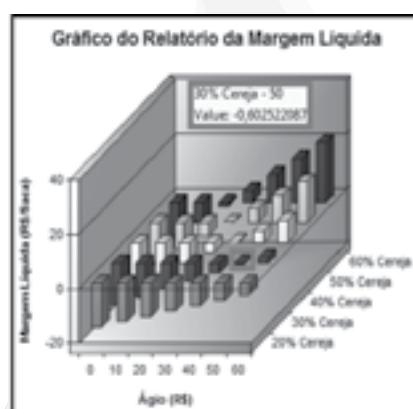
**PA 273**
**A DECISION SUPPORT SYSTEM FOR THE CALCULATION OF COFFEE POST-HARVEST COSTS (*Pós-Café*).**
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Many computer programs were developed in order to calculate the coffee harvest cost. However, a few of them focus on the costs of the stage after the coffee harvest. This way, the aim of this work was to develop a decision support system to calculate the cost of the post-harvest period and therefore, to facilitate the decision making concerning to the best cost-benefit processing to be applied to the coffee at this stage. Forty-eight farms in Brazil, in the South of Minas Gerais, answered a survey made with the purpose of validating this system. When the decision support system was employed, it was observed that the costs at the after coffee harvest stage which were simulated do not differ statistically from the ones informed by the farm managers. The South of Minas Gerais was chosen due to the high quality standard of the coffee produced there, as well as the various types of coffee processing used by farms from this region. This way, the validation of *Pós-café* became more complete.

*Pós-café* consists of a decision support system focused on the analysis of the coffee post-harvest costs, in other words, it employs the human knowledge in order to solve problems which requires the presence of an expert on this stage of coffee processing. The mainly contribution of *Pós-café* is to facilitate the decision making of producers, cooperatives and consultants of the area, concerning to the best cost-benefit processing to be applied during this stage.

Besides the income and cost reports, *Pós-café* generates a graphic related to the net margin. With this graphic, the producer can visualize situations considering several premiums (value in Real related to the difference between the bags of coffee with bigger value of each processing and the percentages of cherry coffee). Conjecturing about these topics the producer can identify in which moment one or other processing is financially viable or not. In the picture it is possible to observe highlighted the point 30% of cherry and a premium of R\$50,00. At this point the net margin is approximately less sixty cents of real (-0,60). In other words, to choose the processing one (1) instead of the processing two (2), at these conditions, will make the producer not to gain sixty cents of real (-0,60).



margem líquida= net margin

café cereja= cherry coffee

ágio= premium

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SOCIOECONOMIC AND ENVIRONMENTAL IMPACT OF  
ORGANIC CERTIFICATION, FAIR TRADE COFFEE (COFFEA  
ARABICA) IN REGION FRAILESCA, CHIAPAS, MEXICO**AGUILAR, Julio\*, SOTO, Gabriela\*, CIFUENTES, Miguel\*, BAUTISTA, Pavel\*, GONZÁLEZ, Cliserio\***

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This research analyzes the impact of two certification schemes, such as organic and fair trade, in coffee producers livelihoods through the application of the Community Capitals Framework, COSA's®<sup>1</sup> toolbox, and the Carbon Footprint. The research compares a sample of 31 producers organically certified, with a control group of 30 conventional non-certified producers. The information has been collected through semi-structured interviews at producers' family level. The results suggest that compliance of organic and fair-trade certification generate social, economic, environmental and human benefits. Certification has contributed to develop and strength the human capital through the generation of technical knowledge applicable to sustainable practices. With regards to the social capital, it has been observed the consolidation of the Cooperative TriunfoVerde's management systems. Concerning the political capital, producers recognized access to better financial terms and conditions for their productive activities. In addition, the impact in the natural capital is observed in the withdrawal of conventional agricultural practices, which reduce the contamination of soil, water and carbon dioxide emissions. In the economic field, even though certified producers benefit from price premium, they don't obtain higher net income (\$2,582.90 USD/ha) in comparison to conventional producers (\$2,550.27 USD/ha). It is required to implement strategies to improve coffee productivity and strength its value added. The results of the estimated carbon footprint reveal a lower greenhouse gas emission in the organic and fair trade production systems (0.11 kg CO<sub>2</sub>e per kg oro coffee), in comparison to conventional production (0.33 kg CO<sub>2</sub>e per kg oro coffee). This lower emission could be used by the Cooperative to design a strategy to look for a certification of Carbon Neutrality. As a result of this research, few aspects are recommended to the Cooperative Triunfo Verde in order to have a greater impact in the development of its economic and environmental capital: (i) to improve coffee productivity, (ii) to promote product differentiation and position in the market by enhancing its value added, and (iii) to strength producers' buy-in, promotion and application of organic and fair trade certification regulation. Especially, if they want to diversify the certification.

<sup>1</sup> COSA: Committee on Sustainability Assessment.

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## DENSITY AND DIVERSITY OF NEMATODE IN THE AGROFOREST SYSTEM OF COFFEE IN ASSOCIATION WITH BANANA AND LEGUME SHADE IN JINOTEGA, NICARAGUA

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Bananas and leguminous trees for shade are commonly found in small holder coffee plantations in northern Nicaragua. Banana growing is a small holder practice to diversify income, but is not recommended by coffee technicians based on the possible role of banana as an alternative host to coffee nematodes. Leguminous trees are recommended both for nitrogen fixation, shade and organic matter. An understanding of the nematode community which includes free-living as well as plant-parasitic nematodes is needed to determine both potential negative or positive interactions. If the plants are hosts-in-common to plant-parasitic nematode species, damage to the coffee plants may be greater than in monoculture. If the plant combinations enhance the functional diversity of soil organisms, including those improving soil fertility or suppressing pest species, the beneficial aspects of the systems may be amplified. In 28 farms in Monterrey, Nicaragua, we studied the effects of coffee-banana-legume combinations on the plant-parasitic nematode community associated with coffee roots and on the functional diversity of the entire soil nematode assemblage. Four plant combinations were evaluated on each farm: coffee-banana-legume (CBL), coffee-banana (CB), coffee-legume (CL) and full sun coffee (C). The coffee variety was Caturra, the banana variety was Gross Michel and the leguminous trees were *Inga* sp. In each treatment we measured % shade, % litter, % weed cover, and soil bulk density. Soil samples were taken for nematode faunal analysis, physical and chemical analysis, and mass of coffee and banana roots. The common plant-feeding nematodes were identified to genus (*Meloidogyne*, *Pratylenchus* and *Radopholus*); the remainder was identified to the family level. Population levels of *Meloidogyne* J2 in coffee roots were greatest where banana was not present (CL and C), contrary to farmers expectations. While *Pratylenchus* levels in coffee roots were greatest in CBL. In banana roots, *Pratylenchus* was at the greatest densities in the CB combination, but lower in CBL. *Pratylenchus* and *Meloidogyne* densities in coffee roots were negative and positively, respectively related to *Pratylenchus* densities in banana roots. The endoparasitic nematodes in coffee and bananas roots, despite being of the same genera, exhibited different relationships with the physical and chemical characteristics of soil, an indication that they are not of the same species or that the nature of the host root has the predominant influence. The soil nematodes were categorized into four trophic groups: bacterivores, omnivores, fungivores and phytonematodes, to provide a broad synopsis of ecosystem function. The trophic groups did not differ significantly among plant combination treatments. Of the soil food web indices derived from the nematode faunal analyses, the ratio of the metabolic footprint of predators to the plant parasites, differed significantly among treatments. For example, the presence of predators was higher in the phytonematodes CBL treatment when I had coffee in the sun. In the systems with greater plant diversity, more bacterivores provide greater resources for predators, however, *Meloidogyne* J2 decreased in coffee roots but increased in banana roots when more bacterivores were present in the soil. The lack of relationship between root and soil populations may underscore the importance of endoparasitism in avoiding predation.

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FUNCTIONAL DIVERGENCE OF BIOMASS PARTITIONING, CARBON GAIN AND WATER USE IN *COFFEA CANEOPHORA* IN RESPONSE TO WATER SUPPLY: IMPLICATIONS FOR BREEDING AT AIMING IMPROVED DROUGHT TOLERANCE

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Robusta coffee (*Coffea canephora*) has been largely cultivated in regions where water availability constitutes the major environmental constraint affecting crop production. The functional divergence associated with biomass partitioning, carbon gain and water use, in response to water supply, was examined in 10 one-year-old clones of robusta coffee with varying degrees of drought tolerance. The plants were grown outdoors in 24-L pots either at full irrigation or submitted to a four month water deficit. Our specific objectives were: (1) to assess the extent and mechanisms of intra-specific variation of carbon gain as related to hydraulic constraints; and (2) to examine sets of traits to identify drought-tolerant clones by analyzing key traits as relevant integrators of drought effects. Under ample irrigation, a higher ability for water use (higher water potential, transpiration rate, apparent hydraulic conductance and biomass partition into roots, paralleling a lower wood density) played a key role for enhanced carbon gain. In sharp contrast, under drought conditions, the preservation of internal water status through more conservative rates of water use was fundamental for maintaining relatively higher stomatal conductance, and hence photosynthetic rates, thus fuelling biomass accumulation. Isotope signatures ( $d^{13}C$  but not  $d^{15}N$ ) may be a useful tool for identifying clones with improved performance under drought. Our results suggest that, by combining proper morphological and physiological traits, it is possible to successfully assess the clonal performance in response to drought at the seedling stage. This may be strategic when exploring a large number of genotypes in breeding programs of coffee by saving time and resources that otherwise would be spent in potentially undesirable genotypes.

Acknowledgments: FAPEMIG

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## EVALUATION OF DRIP IRRIGATION FOR COFFEE CROP CULTIVATED IN ARAXÁ, MG, BRAZIL

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Brazil already irrigates more than 10% of its land dedicated to coffee growing, an area that accounts for 21% of domestic coffee production (SANTINATO; FERNANDES; FERNANDES, 2008). Especially in regions considered marginal with regards to a lack of water, the use of irrigation has become more common for coffee growing; however, correct standards of quantity and handling are not always followed (DRUMOND; FERNANDES, 2001). Therefore, it is necessary to study in detail, and in a comparative fashion, the different systems of coffee tree irrigation, in order to obtain information that can indicate practices to coffee growers,

whether in the recovery of existing plantations, or in the enlargement of irrigated coffee growing in the *Triângulo* region of Minas Gerais state. It is necessary to gather technical and economic data that permit a more appropriate and effective orientation for producers in each situation that arises, as a result of the size and characteristics of the crop, availability of water (quality and quantity), availability of energy and training of workers present. (FERNANDES; DRUMOND, 2002). The generation and adaptation of coffee production technologies under total and supplementary irrigation are essential, to enable continuous and economical high productivity, without leading to degradation of the environment. Most of the experimental work on coffee tree irrigation shows increases of some 20 to 30 beneficiated sacks per hectare, independently of the systems used, and dependent upon the region under study (MATIELLO et al., 1995). In addition to the increase in productivity, it has been noted that irrigation leads trees to blossoming several times, so that a single branch has beans in different stages of maturity. (OLIVEIRA et al., 2002). In the plateau region of Araxá, traditionally coffee is produced economically without irrigation, due to the historical average water deficit of less than 100 mm per year. But in recent years, with climate change, it has been verified years with deficits of 150 mm, affecting plant growth and crop yield. Within this context, the objective was to assess supplementary irrigation to increase production of coffee grown on the plateau of rock phosphate. The treatments were different drought periods (from April to November), compared with total irrigation and without irrigation. After three seasons, it was concluded that the interruption of irrigation on yield losses caused 8 to 33%.

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### USING HYPERSPECTRAL REMOTE SENSING TO CHARACTERISE NITROGEN CONTENT FOR THE PRODUCTIVITY OF COFFEE SYSTEMS IN RWANDA

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Monitoring soil quality is an intrinsic part of modern farming in the world. However, the need to know nitrogen status in coffee farming systems in order to timely use these expensive and limited inputs is a challenge for Rwanda coffee Authority. The study was conducted to characterise the plant nitrogen using spectral reflectance of coffee leaves with aim to find out the quick method of determination of nitrogen as predictor of coffee yield. Relationships between vegetation indices (VIs) from hyperspectral remote sensing and nitrogen content in coffee leaves were determined using generalized linear model. VIs are calculated from calibrated Ocean Optics Red Tide spectrometer data, and the band used are 0.40 nm bandwidth, and a band pass that spans between 339.69 nm to 1025.35 nm. The results were validated using laboratory measured nitrogen in the soil and leaves. Coffee plots used in the experiment are located in acidic soils in the south plateau of Rwanda with pH varying between 3 and 5. The average value of organic carbon is 2.5%, common for moderate humified soils of Rwanda. Soil nitrogen content is also moderate (0.20%). Form five vegetation indices considered in the experiment, three are selected to characterise leave nitrogen in coffee systems of Rwanda. A strong relationship is found between the Normalized Difference Vegetation Index (NDVI:  $R^2=0.96$ ), the Red Edge Normalized Difference Vegetation Index (RENDVI:  $R^2=0.82$ ) and the Simple Ration Index (SRI:  $R^2=0.74$ ) with the nitrogen measured in the 3<sup>rd</sup> and 4<sup>th</sup> young leaves. However, the relation degraded when these indices were modified.  $R^2$  dropped from 0.82 to 0.30 when SRI was modified to MRESRI and from 0.82 to 0.25 when the RENDVI was modified to the Red Edge Position Index (REPI). With these findings, we concluded that the NDVI, RENDVI and SRI value are alternative indices of nitrogen content in coffee leaves as predictor of yield. However, further studies are needed at yield level to create a robust and effective method of monitoring coffee systems productivity. The method could be timely effective in predicting the actual leaf nitrogen and chlorophyll content as predictor of seasonal yield production.

**Key words:** Vegetation Indices, Hyperspectral Remote sensing, Coffee, Rwanda

**PA 279**

**NITROGEN SUPPLY IN THE CONSORTIUM  
BETWEEN COFFEE AND FORAGE PLANT**

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The use of the consortium in the cultivation of coffee in full sun, provided there is no competition for production, reduces water loss by evaporation and passes through the cycling of nutrients between the lines for coffee, with the decomposition of waste under the canopy. In this production system, increasingly used by farmers in Brazil, the presence of grasses reduced erosion, a fact that should contribute to the maintenance of soil fertility and the efficient use of nitrogen (N). However, there is doubt as to the mode of application of nitrogen fertilizer should be done on the forage, coffee or both in the broadcast application. For this research an experiment was installed on green-house. The seedlings of Coffea arabica cv. Mundo Novo IAC 379-19 were planted in pots containing 25 L of a mixture of 70% soil and 30% sand. The dose of N used in coffee plantations (300 kg ha<sup>-1</sup>) was applied either directly on the tree, sometimes in forages (*Brachiaria brizantha* cv. Marandu) and in both half and half coffee in the forage, which was grown in plots of 30 m<sup>2</sup>, without N, and with 150 and 300 kg N ha<sup>-1</sup> in the form of ammonium sulfate. In that all coffee N was applied to the coffee seedlings were conducted without the addition of the forage plant residues, as well as its presence. In this case, the fodder has not been fertilized with N. The forage used to simulate the consortium with the coffee was the *Brachiaria brizantha* cv. Marandu, whose nitrogen source was 45 days before the cut biomass. After cutting a sample of 500 g of fresh plant material, was placed in container nylon mesh 4 mm<sup>2</sup> to 30 x 30 cm, to prevent loss of residual evaluations of decomposition of the plant residue. The growth of coffee was estimated by plant height. Samples of fresh and decomposing *Brachiaria* were collected to determine the total concentration of N-and C / N ratio, and the N concentration in the tissue of the coffee leaves. At the end of the experiment was also evaluated the dry matter, leaf number and leaf area of coffee, and the remaining biomass of signalgrass under degradation. The nutritional status of coffee was not impaired when the nutrient was delivered via cycling of the biomass of grasses fertilized with N. The dry matter and leaf number was higher in coffee conducted in the presence of residue of forage fertilized with N. The plant residue poor in nitrogen showed higher C / N and lower N-leaf in the coffee plant.

**PA 280**

**THE SUSTAINABILITY OF COFFEE-BASED RURAL LIVELIHOODS: A STUDY OF SOCIAL AND ECONOMIC CHANGE IN RURAL INDONESIA**

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Indonesia was the world's third largest coffee producer after Brazil and Vietnam in 2011 (slightly exceeding Columbia that year according to the ICO). Within Indonesia, coffee is the fourth most important source of agricultural export earnings after rubber, oil palm, and cocoa. However, Indonesia has a large and diversified economy, such that coffee contributed less than 1% to total export earnings in 2010, and the sector receives relatively little real policy support as a result. More than 95% of the total land planted to coffee in Indonesia is managed by an estimated one million smallholders, who typically cultivate less than one hectare of land in isolated regions with poor access to social services. Smallholder income tends to oscillate either side of the poverty line depending on conditions in world commodity markets. While coffee farming rarely provides a reliable pathway out of rural poverty in Indonesia, coffee farming does perform an important social security function by injecting cash into otherwise impoverished rural areas.

The natural resources that coffee production relies upon in Indonesia, most importantly land, are under increasingly pressure from alternative functional uses, including commercial crop production (eg. palm oil and rubber), domestic food production (rice, corn and cassava) and ecological services (carbon sequestration, watershed protection and habitat provision). Similarly, sustained coffee production also requires the allocation of adequate human resources. This paper presents the findings of a livelihood survey of rural households across Indonesia where coffee farming constitutes an important source of cash income. Results indicate that, notwithstanding relatively high global coffee prices during the study period, coffee farming is perceived to be a poorly remunerative economic activity of last resort. It is felt to be incapable of offering a genuine poverty alleviation pathway that might allow rural Indonesian households to meet increasing social expectations in terms of education and health. The results also suggest that certification schemes, aimed at improving rural livelihoods in Indonesia, have yet to generate significant effects at the farm level.

The sustainability of future global coffee supplies requires all actors within the global value chain to demonstrate a substantially heightened interest in facilitating socially attractive coffee-based livelihoods in origin countries. This commitment will need to move well beyond existing commercial relationships between actors along the chain, and probably beyond the dependence on existing certification regimes to deliver sustainable livelihoods.

**PA 281****ESTIMATION OF SHADOW HOURS IN FUNCTION OF LATITUDE,  
SPACING AND HEIGHT OF PLANTS IN AGROFORESTRY WITH  
COFFEE IN NORTHEAST AND SOUTHEAST OF BRAZIL**

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The agroforestry systems (SAF's in Brazil) with coffee could contribute to the expansion of Brazilian coffee plantation, particularly in areas that presents high solar radiation and temperatures. The shading time depends on the latitude, the distribution of the tree rows, the height of the trees and the spacing between them. The spacing is dependent on variations in declivity and ground exposition to the sun light. In Brazil, shading of 25 to 50% of the surface is recommended depending on the region. How much nearer the farming is of the Equator, the greater must be the shading due the incident radiation, however, the higher the latitude, as higher should be the insolation time in the summer. The management of shading trees in SAF's would be more efficient whether the direction of planting, thinning and pruning follows the North-South alignment. Thus, the coffee trees would be shaded in some part of the day. However, there are no appropriate recommendations of how estimating the spacing between the many species of trees that could be used to promote the appropriate shading of coffee trees, which difficult the planning of implantation of SAF's. The objective of this work was to propose a methodology to estimate hours of shading in function of latitude, spacing and height of plants in SAF's with coffee trees. Plants that were not shaded were called plants with N hours of direct insolation. The N value can be modeled by the software ArcGis, considering the shading produced by the relief in function of latitude and the digital model of elevation. The shading time can be estimated by the angle formed by the sun light inclination and the height of the shading tree in a particular spacing on the soil surface. The application of this methodology allowed estimating spacing between trees to SAF's in two municipalities of two Brazilian regions (Northeast and Southeast). The equation was implemented in a System of Geographic Information (ArcGis), in which the spacing between trees and its height were provided as well as the local latitude and the digital model of elevation of the area. In the Northeast region this study was done in Guaramiranga, State of Ceará, latitude 4° 15' 48"S, where 50% of shading in the coffee trees is recommended; and in the Southeast region the study was done in Araponga, State of Minas Gerais, latitude 20° 40' 00"S, where 25% of shading is

recommended. The native tree species and fruit trees that are commonly used in each region were listed and grouped by height. The results allowed recommending the adequate spacing in function of the shading time of the coffee trees in SAF's in diverse conditions of insolation. The more adequate spacing in Guaramiranga varied from 5 to 20 m between trees of 5 to 25 m height. In Araponga the spacing varied from 10 to 50 m between trees of 5 to 25 m height. The authors acknowledge the support received by the FAPEMIG.

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### SUSTAINABLE COFFEE LEADERSHIP PROGRAM: A MODEL PROGRAM TO TEACH AND SPREAD SUSTAINABLE PRODUCTION METHODS TO COFFEE FARMERS THROUGH PRODUCTIVE ENGAGEMENT.

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**Problem.** Due to the prevalence of unsustainable farming practices, along with the onset of climate change, Costa Rican coffee farmers will not be able to maintain current levels of production on their farms. Many local farmers do not recognize the need to change their unsustainable practices, nor do they have the experience, knowledge or tools to make those changes or to cope with climate change.

**Approach.** To address this lack of guidance, Earthwatch with the support of Starbucks Coffee, spent several



years working with farmers at a local coffee cooperative to develop a sustainable farming program with goals to: Encourage farmers to improve the sustainability of their farms through the incorporation of tools to make better management decisions; promote the sustainable use of natural resources; develop a participatory methodology for continuous training within the cooperatives with collaboration from farmers and technicians; and promote knowledge exchange networks among farmers within the cooperatives. This program resulted in workbooks, soil analysis tools, logbooks, surveys, course curriculums and evaluation questionnaires for

a series of six Sustainable Coffee Leadership Program workshops. In 2011, the workshops were held at four of Costa Rica's strongest coffee cooperatives with participation from 128 farmer members. The workshops covering the following topics: Record keeping and economical analysis; pests and disease management; climate change and carbon footprint; the sustainability concept; soil fertility management; and shade and weed management.

**Results.** Overall, farmers' evaluations were highly positive in all six workshops. As a direct result of participating in the Leadership Program, farmers planted an increased number of shade trees on their farms and modified pruning practices of existing trees. They reduced the potential for erosion while improving soil quality through the reduction of herbicide use and the increase of manual weeding practices. The majority of farmers recognized that their current practices were damaging soils, resulting in the increase of soil analyses as well as liming, and farmers expressed a strong desire to implement soil analysis in the upcoming year. As a measure of the program's positive impact, participants highly recommended the expansion of the program to more farmers within their cooperatives and to other cooperatives as well.

**Conclusion.** Earthwatch is incorporating lessons learned from the workshops to improve the Leadership Program while exploring how best to expand participation through legacy visits within the current four cooperatives, visits to additional cooperatives, and developing an online presence to deliver training materials to more cooperatives within Costa Rica and to farmers in other Latin American countries.

## PA 283

SUCCESS FACTOR FOR COLLECTIVE BANANA MARKETING  
BY SMALLHOLDERS IN CENTRAL AMERICA**BANTLE, Christine,\***

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The purpose of this study is to identify the success factors for the collective marketing of bananas by small farmers in Central America. The study focused on social and human capital factors that are effective in groups, which are in the pre-marketing phase (and have not yet begun marketing). Data were collected through qualitative interviews and participatory research methods. There were 19 interviews and six participatory workshops. The results show that for a successful collective marketing of bananas, high levels of social and human capital are required. The factors that influence success are specific from the product and the group's development level. The study was part of a research project dealing with the marketing of bananas being coordinated by Bioversity International. The field work took place in four pilot areas where the project is developed, two areas in Honduras and two in Nicaragua. The pilot group members participated in both interviews and workshops. The workshops were used for data collection and improvement of cooperation within groups. In addition to producers who had experience in bananas marketing, representatives of the supporting agents were interviewed. Relative to qualitative research approach, the success factors that emerged from interviews and workshops were not representative, but are valuable for the project. Relative to internal social capital (within groups) within the central factors of success, motivation, guidance of producers in the long term and trust among members. Especially in the pre-marketing phase, when the benefits are for the future and producers are not used to work together (in the current group). The clear demarcation (definition) of the group can help with the increased confidence among producers. With security, the rules establishment and appropriate controls are also very important. The human capital factors, knowledge management is a pre-existing success factor because it can shorten the time needed in external support, as the banana marketing demand volume handling. Producers also need to know the risks of bananas marketing, which are particularly related to the deterioration and unstable prices. Knowledge is important to make decisions about the viability of collective marketing, to choose an appropriate strategy for marketing and to consider the risks in the costs calculation. Among other important skills are: the familiarity with potential markets and demands. In any case, producers must have the ability to produce the quantities and qualities demanded. For the different challenges in pre-market phase, the group's access to external support (social external capital) can determine success. Although it depends on the case, support may be necessary in establishing the organization in handling bananas, and in developing a marketing strategy. The staff support is also important because they can supply the producers for information and expertise on the bananas marketing. Probably, most of the groups require support for more than 3 years, which is the regular length of the project. Therefore, the feasibility of long-term support is also a success factor. Finally, we showed that a higher consideration of gender is probably a marketing advantage for collective marketing: the groups can benefit from the different abilities of women and men, and the fact that women have more access to external support.

## DEVELOPMENT OF POLICY TOOLS FOR MEASUREMENT, MANAGEMENT AND VERIFICATION OF CARBON FOOTPRINT IN THE PRODUCTION, PROCESSING AND MARKETING OF COFFEE FROM COLOMBIA

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The National Federation of Coffee Growers (FNC) since its establishment has maintained an ongoing commitment to the environment and overall sustainability (environmental, economic and social) of coffee production, which at present is evident in its Strategic Plan 2008 to 2012, clearly defines in its value proposition **Competitiveness and Innovation** as a strategic objective, « lead initiatives that generate a positive impact on the environment» and a strategy «actively participate in carbon markets and environmental services.»

In relation of carbon footprint measurement, since 2007 Cenicafé has been generating knowledge through various researches in the production chain, processing and marketing of coffee. Based on this information is intended to create tools that allow:

- Standardize criteria concerning the measurement and management of carbon footprint in production, processing and marketing of coffee in Colombia.
- Provide to coffee, agriculture and country's productive sectors overall, standards that allow the measurement and continuous improvement management that will contribute to mitigating greenhouse gases (GHG) emissions, from a country view
- Provide consumers with information verifiable, replicable, sustainable and reliable.
- Generate differentiating components that allow the product position (goods and services).

In order to advance in the development of regulatory tools, The National Federation of Coffee Growers - Cenicafé signed a cooperation agreement with the Colombian Technical Standards and Certification institute - ICONTEC, with the following objectives:

- **Standard:** Standard structure proposals to unify criteria for the calculation and management of Carbon Footprint of goods and services.
- **Certification:** design a certification scheme that allows, based on the rules, certifying measuring and managing the carbon footprint of products (goods and services).

To validate these instruments, with the participation of companies in the coffee Institutional and strategic partners, was conducted to measure the carbon footprint of a representative volume of coffee through the production chain , processing and marketing of Colombian coffee .

Carbon strategy implemented by the FNC can provide the necessary technical and scientific support to the production chain , processing and marketing best practices are adopted consistently contribute to the efficient use of energy, reducing emissions, strengthen the Culture of Sustainability and the generation of distinct elements of Colombia's coffee.

**PA 285**

## **WEED CONTROL EFFECTS ON COFFEE INTERROWS ON COFFEE**

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EPAMIG Southern of Minas Gerais state, Brazil

**ABSTRACT:** The coffee crop is very sensitive to competition from weeds. The weed control in the rows and coffee interrows is responsible for a production cost which is around 30%. Because of this, various weed control methods have been used as a way to minimize or eliminate the weed competition at coffee interrows, at a compatible cost and a sustainable management and production. With this objective was implemented in September 1977 at the EPAMIG Experimental Station in São Sebastião do Paraíso, MG in coffee crop planted in January 1974 in Red Oxisol, spaced 4.0 x 1.0 m with a coffee cultivar IAC Catuai 99, an experiment using 2300 plants in an area with 8% slope. A randomized complete block design was used with seven methods (treatments) of weed control at coffee interrows, namely: mower, harrow, rotary tiller, post-emergence herbicide (glyphosate at a rate of 720g/ ha), pre-emergence herbicide (simazine + ametryn at a rate of 250 +250 g/ ha), hand weeding and control without weeding, in three replications. The coffee rows were always kept clean by hand weeding and / or herbicide application. Several parameters about soil qualities and coffee development in this experiment were evaluated; however, this work will be focused only on the effects on production. From 1978 to 2005 the yields were grouped into biennia and annual yield totaling 15 repetitions In 2006 this experiment was replanted, keeping the same interrows spacing, but with 0.70m/ plant at rows, but using the cultivar called Paraíso, MGH 419, keeping the same treatments at interrows, using as pre-emergence herbicide oxyfluorfen to 3,0 liters of commercial product / ha. The last four years yields from 2008, 2009, 2010 and 2011 were also analyzed as the last one. After 35 years results show that coffee crop with the interrows always kept free of weeds with pre-emergence herbicide, always results in higher productivity. The interrows without weeding (control) had the lowest production. The use of harrow, rotary tiller and post-emergence herbicide, presented an intermediate production, because these methods depend on the anthropogenic action, i.e., depend on the time interval of the weed control operations. The mower pulled by tractors, widely used by most growers, showed only higher yield than treatment without weed controls. This result has been explained by overuse of the implement at rain periods, when the weed growth requires control every 25 days, resulting in a compressed region on the tractor wheels track due to a wet soil, where are great part of the root system that absorb nutrients.

**Keywords:** Control weeds, coffee, production

PA 286

IDENTIFICATION OF NATURAL ENEMIES OF THE COFFEE BERRY BORER (*Hypothenemus hampei*) IN COSTA RICA**ROJAS, Mainor; MORALES, Javier; DELGADO, Carlos**

Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)

With the purpose of identifying the insects in the fruits infected with the coffee berry borer and their relation with the plague as potential agents for natural control, 15 coffee farms with different characteristics of height, weather, soil, variety, density, shadow and management were selected for sampling in the Turrialba region. Samples were collected from coffee fruits that remained in the plant and on the ground in the 2009/2010 harvest, during March, April and May 2010, and from mature fruits in the 2010/2011 harvest, during August and September 2010. The coffee fruits samples were taken to the Phytoprotection Laboratory of CICAFE. Of all the fruits infected with the coffee berry borer, a representative number was dissected in order to find potential biological controllers. The others were stored in plastic boxes with a lid that allowed aeration, to keep them for a month with a temperature of 27°C (80.6°F) and 75 percent relative humidity. The fruits were kept hydrated and each week they were exposed to light to stimulate the emergence of potential biological controllers.

The main insects associated to the remaining coffee fruits infected with the coffee berry borer in the 09/10 harvest were *Lyctocoris* sp, ants and *Blastobasis* sp, in the plant, together with pseudoscorpions on the ground. The number of insects, except for the pseudoscorpions, was higher in the coffee fruits left in the plant than those on the ground. In the fruits infected with the coffee berry borer at the beginning of the 10/11 harvest only ants were found.

Preliminary lab tests assessed the predaceous capacity of the coleopterous pests *Cathartus quadricollis*, *Ahasverus advena* and *Lyctocoris* sp. The three insects showed high predaceous capacity in the biological states of the coffee berry borer, although the *Lyctocoris* sp showed higher voracity and was the only one predator of adult coffee berry borer. A single *Lyctocoris* sp. preyed upon over 40 eggs of coffee berry borer during 10 days; the *C. quadricollis* ate almost 40 and the *A. advena* ate over 33. During its nymphal stage (24 days) *Lyctocoris* sp. predated on average 119 eggs, 116 small larvae, 131 large larvae, 45 pupae and 39 adults of coffee berry borer.

## PA 287

THE CRESPERA DEL CAFE IN COSTA RICA  
AND ITS ASSOCIATION TO *Xylella fastidiosa***BARQUERO, Miguel, ROBLES, Alejandra, ARRIETA, Noel.**

Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE), Barva, Heredia, Costa Rica

In Costa Rica, the "Crespera del café" is a physiological disorder which symptoms are not always present in the entire plant. These symptoms are visible in the leaf deformation: bifurcation of the midribs, serrated edges, raised midribs, chlorotic spots and a coriaceous appearance that not always covers the entire leaf. There may be a proliferation of secondary axes in the upper third of the orthotropic axis with the shortening of internodes. It is also possible to notice a growth distortion forming a slightly spiral, while the plagiotropic growth affected is characterized by short internodes, particularly in those leaves with the disorder symptoms. During 2006-2010 several field studies were conducted in areas which presented the symptoms, and laboratory studies were made in the Phytopathology Laboratory of CICAFE, with the purpose of understanding the dynamics and spread of this disease, both in the plant and in the coffee plots, and the symptomatology relationship with or without *Xylella fastidiosa*. These studies were also intended to evaluate different antibiotics in the development of the symptoms through several consecutive years. The results from these studies reported that the *X. fastidiosa* bacterium was detected in 97,5 percent of the coffee plantations; however, the symptoms in the field do not match the proportion of the bacteria that is present. Moreover, the spread of the disease in the plant did not follow a specific pattern; most of the bacteria were concentrated in the plagiotropic tissues of the middle and upper stratum of the plant. Asymptomatic plants were positive in the DAS\_ELISA test. No association was observed between the progress of the symptoms and the concentration of bacteria in the plant; the antibiotics did not reverse the symptoms or prevented the emergence of new ones.

## PA 288

EPIDEMIOLOGY OF *Mycena citricolor* IN COSTA RICA**BARQUERO, Miguel, ARRIETA, Noel, ROBLES, Alejandra.**

Costa Rican Coffee Institute (ICAFE), Center for Coffee Research (CICAFE)

*Mycena citricolor*, pathogen causing the disease known as "Ojo de Gallo" or also called American leaf spot of coffee, is the most serious coffee disease in Costa Rica, and it is responsible for considerable economic losses every year. This disease decreases yield performance and causes premature exhaustion in coffee plantations, particularly in areas in which the environmental conditions are favorable for the development of the *Mycena citricolor* pathogen. Considering the influence of climatic conditions on the gemmae formation of *M. citricolor* and their germination on coffee leaves, a study was conducted from 2008 to 2011 in the coffee region of Poás, province of Alajuela, Costa Rica, at 1450 m.a.s.l., to examine the progress curve of the disease and variations in temperature, rainfall, relative humidity and hours of leaf moistening. Throughout the study, the climatic conditions were influenced by the natural phenomena "El Niño" and "La Niña", which clearly had an effect on the progress of the disease in either a positive or a negative way. The influence of leaf moistening and rainfall, and their frequency or intensity was determined as the main factors contributing to the development of the disease. This paper discusses the importance of describing and monitoring the climatic conditions for the analysis of the impact of this disease in different coffee regions of the country, as well as the implications on decision-making for the appropriate establishment and management of the coffee culture to achieve an integrated disease management.

PA 289

SELECTION OF COFFEE PROGENIES F<sub>4</sub> PROCEDURE  
USING REML / BLUP

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The objective was to select progenies of coffee plants in the F<sub>4</sub> generation for agronomic traits and disease resistance through the REML/BLUP. The experiment was installed in January 2007, at the Experimental Farms of EPAMIG (Agricultural Research Company of the State of Minas Gerais) in Machado, Minas Gerais, Brazil, being used 33 coffee progenies derived from crossings between the cultivars of the group following Icatu (Icatu Amarelo IAC 2944, Icatu Vermelho IAC 2942, Icatu Vermelho IAC 4040 and Icatu Vermelho IAC 4042) with cultivars Catuaí Amarelo IAC 62 and IAC 17 and the progenies IAC 5002 and IAC 5010. As control were used Catuaí Amarelo IAC 62, Rubi MG 1192 and Topázio MG 1190. The experimental design was a 6 x 6 square lattice with four replications and 10 plants per plot and the assessments in the years 2010 and 2011. The characteristics evaluated were: productivity in bags.ha<sup>-1</sup>, production in liters.plant<sup>-1</sup>, percentage of grains retained in sieve '17 and above 'and reaction to rust, vegetative vigor and reaction to Cercospora leaf spot, through a rating scale. In the statistical analyzes, we used a split plot in time, by using the statistical program SELEGEN through the REML / BLUP. It was found by analysis of genetic parameters for productivity, reaction to rust and sieve '17 and above ' the selection of families from provide higher gain compared selection between plants, as the genotypic variance, heritability and coefficient of variation on showed more satisfactory. The analysis by plants, there was an increase in genetic variance and heritability for production, reaction to Cercospora leaf spot and plant vigor, thus selecting the best plants would be more advantageous for these characteristics. We used 5% selection intensity, totaling 72 plants from the genetic effect for individual production and consequently for reaction to Cercospora leaf spot and plant vigor. We selected 37 individuals from 13 progeny, 32 individuals from 9 progeny, 2 individuals of the progeny 2 and 1 of 32 individual progeny. The progenies 13, 32 and 2 are derived from the crossing Icatu Amarelo IAC 2944 and Catuaí Amarelo IAC 62 and the 9 progeny, the crossing between Icatu Vermelho IAC 4040 and IAC 5010. The new average of the selected plants for the three traits was above the overall average of progenies and cultivars used as control. The additive genetic gain predicted with the selection of plants was 16,84, 16,59 and 2,19% for production, reaction to Cercospora leaf spot and plant vigor, respectively. It follows that from this population is possible selection of superior plants from the genetic effect predicted for production, obtaining simultaneous gains for resistance to Cercospora leaf spot and plant vigor, having thus maximizing the genetic gain per selection cycle.

**PA 290**

## **CHARACTERIZATION OF ARABICA COFFEE ACCESSIONS OF EPAMING GERMPLAM BANK**

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\*Indonesian Coffee and Cocoa Research Institute (ICCRI), Jember, East Java, Indonesia.

The aim of this work was to characterize Coffee Germplam Bank accessions of Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG) in relation to some physical, physical-chemical and chemical traits of grains and sensorial analysis. Size and shape of the classified grains were determined in the physical traits by sieves, time and uniformity of fruit maturation. The physical-chemical and chemical components analyzed were the following: electric conductivity, potassium leaching, moisture content, color index, soluble solids, sugar content (total, reducing and non-reducing), titratable acidity, polyphenoloxidase activity and caffeine content in the grains. Sensorial attributes were evaluated for quality of the coffee drink according to criteria of "Brazil Speciality Coffe Association-BSCA", which were the following: "clean cup, sweetness, acidity, taste, aftertaste, overall and total balance. Regarding classification by sieves, 46.4% of the accessions presented from 70 to 92.8% grains classified in sieve 16 or above. This characteristic of the large grain is much valued especially in the marked of speciality coffees. For fruit maturation time, accessions were distributed into early maturation (19.9%), semi-early maturation (25.3%), average maturation (19.3%), semi-late maturation (17.5%) and late maturation (18.1%). Regarding uniformity, 11.5% of the accessions were uniform maturation, 33.7% median uniform and 54.8% were not uniform. Concerning physical-chemical and chemical components, most accessions presented values close to the ones cited in literature. Discrepant values may be attributed to genetic variability inherent to the studied genotypes. In relation to the total score of sensorial analyses, accessions presented mean of 82.2 points, with a minimum of 65.0 and a maximum of 90.0 points. Of the evaluated samples, 48.2% presented scores equal to or higher than the average. Those results show that a great percentage of accessions presented cup quality potential for production of special coffees. Some accessions of Bourbon Amarelo (MG0009), Bourbon Vermelho (MG0011, MG0014), Híbrido de Timor (MG0304, MG0313, MG0338, MG0339, MG0357, MG0369), Mundo Novo Purpuracens (MG0138), Caturra Vermelho (MG0187), Bourbon N39 x Híbrido de Timor (MG0554), BE 5 Wush-Wush x Hibrido de Timor (MG0540), Caturra Vermelho x DK 1/6 (MG0651, MG0654), Caturra Vermelho x S 795 (MG0926), Icatu Amarelo IAC 2944 (MG1188), Catimor (MG1156), Catimor Planta 09 (MG1157), Sarchimor (MG1059), Cavimor (MG1079) and Mundo Novo IAC 388-17-16 (MG1256) stand out for a higher cup quality since two cuppers gave them average scores equal to or higher than 85 points. The results from this work will be used to enlarge the knowledge baseline on accessions of Arabica coffee preserved in the germplasm bank of EPAMIG and they will be used for cataloging and documentation on the genetic collection of this Bank. The catalogued data aim at subsidizing selection of potential parents for coffee genetic breeding programs and for other correlated studies.

Financial support: FAPEMIG, Consórcio Pesquisa Café and CNPq.

**PA 291**

**EXPLOITING GENETIC DIVERSITY TO IMPROVE COFFEE QUALITY**

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Among the 124 recently reclassified *Coffea* species 19 are represented in the germplasm collection of Instituto Agronômico. Though precious, it is a fraction of the biodiversity. Even less has been effectively exploited in practical breeding programs, exceptions being *C. canephora* source of nematodes and rust resistant genes, *C. liberica* donor of *SH<sub>3</sub>* rust resistance allele and *C. racemosa* origin of leaf miner tolerance. Regarding to cup quality, examples are confined to rare attempts, hindered by the concept that little value exists outside the gene pool boundary of established *C. arabica* cultivars. Nevertheless, exploratory investigations of available genetic diversity, is a straightforward strategy to access complex interactions of flavor profiles that could be expressed after wide hybridizations and ensuing genetic recombinations. Unique profiles are open avenues for the evolution of market demands and opportunities of new consumer niches. In this line of investigation, many genetic recombinants have been generated, mostly backcrossed in different intensities to cultivars, planted in breeding plots in Campinas for agronomic observations, bean characterization and cup profile evaluations, notwithstanding that Campinas is not a specialty coffee producing region. As expected, the majority of such germplasm failed at agronomic performance, had severe bean defects or odd tasting beverages. Some with potential traits were used in crosses, generations advanced on the basis of selections that presented profile notes distinct of regular cultivars. One of them are crosses of Ethiopian accession Glaucia to several cultivars, the most promising F<sub>4</sub> lines Catuaí x Glaucia displaying uniform ripening, SCAA scores 83,5 (Catuaí 74, Obatã 76) with distinct citric orange lime notes found in Harar coffees. Other cup promising group comprises lines derived of crosses of Obatã, Tupi, Erecta, Nanico and *C. racemosa* backcross derivatives with Mokka, an early small round fruited good tasting arabica mutant. Eight early maturing progenies scored 81 to 86 with varying but interesting fruity cup profiles, with orange acidity, nuts and dark chocolate notes. Unparalleled exotic profile is displayed by some early S<sub>3</sub> selections of *C. arabica* x (*C. salvatrix* x *C. racemosa*)4n with high outturn black fruits, mostly peaberry beans that scored 84-85 with strong remarks of a sweet unique profile without astringency and a pleasant red wood winey taste with fruity, berry-like aroma. F<sub>1</sub> arabustas (*C. arabica* x *C. canephora* 4n) are invariably heterotic setting fruits abundantly, but commercial cloning is precluded by the outcome of meiotic abnormalities, low outturn and defective beans. Flavor is intermediate between genitors but conspicuously segregate out in F<sub>2</sub> as vigor, fruit set and normal beans allowing identification of promising F<sub>2</sub> segregants of crosses with cvs. Ibairi (Mokka) and Obatã. Genes of *C. eugeniooides*, the evolutionary female genitor of *C. arabica* have been introgressed into Obatã, an inbred cultivar with lateness and rust resistance genes from *C. canephora*, the male genitor counterpart of *C. arabica*. From 126 Obatã backcrosses (BC<sub>2</sub>) of *C. arabica* x (*C. eugeniooides* 4n x *C. arabica*), 36 F<sub>2</sub>BC<sub>2</sub> progenies have been selected, agronomic evaluated and cup tested. Compared to Catuaí and Obatã that scored 74-76 with normal remarks, 5 good yielding progenies scored 70-80 but 16 scored 82-86 with relevant descriptions of chocolate-like and lemon grass aromas, orange-lemon acidity, salty-fruity taste, floral nuances, long lasting smooth aftertaste. Sister lines have shown similar trend of good yields, higher cup scores in the Amazonian Rondônia State where late and very late F<sub>4</sub>BC<sub>2</sub> lines are trued up.

## PA 292

ISOLATION, IDENTIFICATION AND UTILIZATION  
OF PHOSPHATE SOLUBILIZING BACTERIA  
ISOLATED FROM COFFEE PLANT RHIZOSPHERE**BAKO, John Bako\*, WEDHASTRI, Sri \*\*, KURNIAWAN, Andi\*\***

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Phosphate solubilizing bacteria isolated from rhizosphere of coffee plants may play important role in improving phosphate availability for the plants. However, one of the factor influencing the degree of phosphate solubilization by these bacteria is the ability of the microorganisms to utilize phosphate. The objective of this study was to determine the ability of phosphate solubilizing bacteria isolated from coffee plant rhizosphere and their effects on robusta coffee seedling growth. This research was carried out by taking soil samples from Andungsari (Bondowoso District) and Kaliwining (Jember District) coffee plantations, both located in East Java. Liquid medium of Pikovskaya was used for isolation of phosphate solubilizing bacteria from the soil samples. Results of this study showed that twelve phosphate solubilizing bacteria were obtained from this isolation, eight isolates from Andungsari and four isolates from Kaliwining. Selection of those bacteria isolates was based on the qualitative ability in phosphate solubilizing by measuring the clear zone surrounding the colonies and quantitatively by measuring the solubilized phosphate using spectrophotometer. The results showed that four isolates, in the order of PF<sub>p</sub>KW1, PF<sub>p</sub>C61, PF<sub>s</sub>C62a, and PF<sub>s</sub>B11, had the highest qualitative ability in solubilizing phosphate, while for the highest quantitative ability the order was PF<sub>p</sub>KW1, PF<sub>p</sub>C61, PF<sub>s</sub>C62a, and PF<sub>s</sub>B11. In a green house study, inoculation of these selected isolates onto Robusta coffee seedlings positively enhanced the coffee seedling growth. Phenotypic test indicated that the four isolates are similar to the genus of *Pseudomonas*.

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## PA 293

GREEN BEAN PHYSICAL CHARACTERISTICS OF PROMISING  
ETHIOPIAN ARABICA COFFEE ACCESSIONS IN BRAZIL**GIOMO, Gerson S.\*, SAATH, R.\* , SILVAROLLA, Maria B.\* , IOBBI, Angélica de C.\***

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The Agronomic Institute (IAC) is the oldest Brazilian Coffee Research Institution and has studied arabica coffee since 1887. In 1932 it was established a consistent breeding program to study genetic aspects of *Coffea* spp and to select high yield arabica coffee cultivars aiming to improve the Brazilian coffee production. The results were definitively important to Brazil that nowadays is the world's largest producer and exporter of coffee. The Brazilian improved arabica coffee cultivars like Mundo Novo and Catuai released by IAC a long time ago are still predominant in all Brazilian coffee regions, occupying at least 80% of the cultivate area. Despite of the enormous success obtained in this breeding program, the narrow genetic variability encountered in coffee plants derivative from Typica and Bourbon varieties has limited the selection of new coffee varieties for physical bean quality. Aiming to enlarge the genetic variability it was introduced several arabica coffee varieties from Africa, India and Central America. In 1964 the Food and Agriculture Organization (FAO) promoted a collect of wild coffees in Ethiopia and several accessions were introduced in Brazil after 1970. During over 30 years of intensive research it was observed genetic variations including semperflorens and erect types, sterile male and low or high caffeine content in the beans, confirming the existence of large genetic variability into

Ethiopian germplasm. Recent studies have been focused on the green bean physical characteristics like size and shape aiming to identify genetic variability for bean physical characteristics. Together the beverage quality some green bean physical attributes are important aspects for the coffee price determination at specialty coffee market. In this study it were evaluated up to fifty wild coffee accessions from Ethiopia, some commercial cultivar as control and some advanced hybrids in order to identify promising genotypes to improve the physical coffee quality. The experiment was carried out during 2010/2011 crop year at Campinas Experimental Center, Sao Paulo State, Brazil. Healthy and fully ripe fruits were selectively handpicked from individual plants and prepared by dry processing procedures (natural coffee). The coffees were sun dried over elevated screens to final moisture content of 11 to 12%. After hulling the beans were graded by size using screens with circular and oblong perforations to determine the retention. It was observed expressive differences for larger and medium flat beans and for peaberry percentage among the genotypes. Considering that all coffees samples were from the same crop year, the same environmental conditions and the same dry processing method, it is supposed that these differences could be attributed to genetic effects. For the control cultivars the percentage of flat beans graded up to 16 inch sieve size varied from 25 to 56% whereas values up to 80% were observed for Ethiopian accessions. Although some Ethiopian accessions showed better green bean physical characteristics than the control commercial cultivar, revealing high potential to improve the physical coffee quality, complementary studies should be done to confirm these preliminary results.

**PA 294****EFFECT OF DIFFERENT SHADE REGIMES ON COFFEE GRADES, BIOCHEMICAL COMPONENTS AND BEVERAGE QUALITY CHARACTERISTICS****KATHURIMA, Cecilia W.**

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Field trials were set up in a low altitude zone. A site was selected with a shade tree casting shadow over coffee trees from 0 to 6hrs of shade in a day in the morning and afternoon plus trees in full sun. Twenty one trees (21) were selected along the path of the shadow and 8 control trees in full sun. Cherry was picked from each tree and processed separately. The coffee was hulled and graded into the standard seven grades used in Kenya. Seven sensory variables were assessed by a trained panel of seven cuppers and rated on a 10-point scale. The biochemical components caffeine, trigonelline, fat and total chlorogenic acids were determined from the coffees. Coffee under 2 to 6 hrs of shade, either in the morning and afternoon, had AB grade proportions of up 80% while the lowest proportion of this grade was observed in coffee under full sun. Highest levels of caffeine were observed in coffee from trees under 6hrs of shade whereas sucrose, total chlorogenic acids and trigonelline showed no clear trend. The results are discussed in relation to possible impact of shade on coffee quality observing that shade/agro-forestry is one of the upcoming changes of coffee production systems to mitigate against climate change.

PA 295

INFLUENCE OF WINDBREAKS ON INFESTATION OF COFFEE LEAF-MINER, *Leucoptera coffeella* (GUÉRIN-MÈNEV. & PERROTTET, 1842) (LEPIDOPTERA: LYONETIIDAE) IN COFFEE PLANTS, 2003-2010**REIS, Paulo Rebelles\***, **PEDRO NETO, Marçal\*\***

\*Empresa de Pesquisa Agropecuária de Minas Gerais - EPAMIG/EcoCentro, Lavras, MG, Brazil, CNPq Researcher, \*\*Universidade Federal do Tocantins, Gurupi, TO, Brazil.

*Leucoptera coffeella* is perhaps the most important pest of coffee plants in Brazil, especially in warmer and drier regions. This study evaluated the influence of windbreaks composed of several species of arboreal legumes (Poaceae) on the incidence of the coffee leaf-miner and its predation by wasps. The experiment was conducted at the EPAMIG experimental farm in São Sebastião do Paraíso, MG, Brazil. The arboreal legumes used were: Guandu (*Cajanus cajan* Millsp.), Bracatinga (*Mimosa scabrella* Benth.) [replaced by Gliricidea (*Gliricidia sepium* (Jacq.) Steud) in 2007], Leucaena [*Leucaena leucocephala* (Lam.) de Wit], and Acacia (*Acacia mangium* Willd.), planted in 1999, in alleys perpendicular to the prevailing winds. The coffee plants were planted in the same year, in strips of five rows parallel to the legumes. The survey started in April 2003, and evaluated the incidence of coffee leaf-miner attacks by counting mined leaves and mines preyed by wasps. The lowest percentages of mined leaves, between 2003 and 2006, were observed in coffee plants sheltered by Leucaena and Guandu, and only presenting more than 30% of leaves mined (level of control to the leaf-miner in the region = CL) in late August-early September, so, chemical control was inappropriate at that time, because of the imminent onset of the rainy season in the region. The effects of the other treatments were similar to the control, and showed an earlier CL in May-June 2003-2006. The influence of the alleys did not reduce the pest infestation in 2007, because in 2006 the alleys were pruned to the same height as the coffee plants. Pruning of the alleys, mostly of Leucaena and Guandu, reduced their effect on leaf-miner infestation, probably because alleys of normal height provide a less favorable microclimate for the pests and also provide shelter for their natural enemies near the coffee plants. In May to early September 2009, after the pruning in 2008, the coffee leaf-miner reached the CL, and the number of mined leaves only decreased in October 2009, with the development of new shoots and the beginning of the rainy season, therefore, no influence of the windbreak was observed. In 2010, with the plants at their normal height, coffee plants near windbreaks of all species showed the lowest infestation rate of the pest until July, and those sheltered by Guandu and Leucaena until the end of September, usually the start of the rainy season in the region. This showed that it was not necessary to use another method to control this pest, because it was adequately controlled by the natural enemies and the microclimate conditions near these alleys (Leucaena and Guandu). Similar results were observed in 2006 (without pruning) and 2007 (after pruning). Of the natural enemies, wasps (Vespidae) were the most abundant: *Polybia scutellaris* (White, 1841) (44.7%), *Brachygastra lecheguana* (Latreille, 1824) (23.8%), *Protonectarina sylverae* Saussure, 1854 (10.5%), *Polybia ignobilis* (Haliday, 1836) (7.9%), *Polybia sericea* (Olivier, 1791) (2.6%), and *Polybia* sp. (10.5%).

**Keywords:** *Coffea arabica*, alleys, Poaceae, Leucaena, Guandu, Brazil.

**Financial support:** Fapemig, Consórcio Pesquisa Café, INCT do Café, CNPq.

**PA 296**

**ADAPTABILITY AND STABILITY OF PRODUCTION  
OF COFFEE CULTIVARS IN ORGANIC CROPS  
SYSTEM IN MINAS GERAIS, BRAZIL<sup>1</sup>.**

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The demand for healthier food produced in sustainable environmental systems has grown substantially in the world, creating opportunities for commerce in several regions. According to IFOAM, in 2009, coffee was the main culture produced in organic system, representing 22.5% (0.54 million hectares) of the cultivated area with permanent cultures in the world. The largest production areas are in Mexico, Ethiopia and Peru. In Brazil, there is no official data about the area and the production of organic coffee, but, according to ACOB, in the season 2005/2006, the organic coffee production in the country was at least 180 thousand sacks, which represents 0.5% of total national production. The organic coffee production, in Brazil, is ruled by Ministry of Agriculture and the use of high solubility manure and chemical products is forbidden. It is fundamental the improvement of researches looking for the development of appropriated technologies to this cropping system. The demands for researches in this subject include the necessity of recommendation of appropriate cultivars. Thus, the objective of this work was to evaluate the phenotypic adaptability and stability of coffee cultivars (*Coffea arabica*) looking for the identification of the most appropriate cultivars for the organic system in the State of Minas Gerais. The experiments were installed in randomized block design, with 30 genotypes (cultivars and lines) and three repetitions. Each plot consisted of ten plants, in which, the spacing between plants and rows were 0.5 x 4.0 m for low-plant cultivars and 0.8 x 4.0 m for high-plants cultivars. The yield was evaluated (bags of green coffee. ha<sup>-1</sup>) in four years (2006, 2007, 2008 and 2009) in three locations in Minas Gerais (Araponga, Espera Feliz and Tombos), with a total of 12 environments. A factorial variance analysis evolving the triple genotypes interaction x localities x years was done. The Eberhart and Russell (1966) methodology was used to analyse the adaptability and stability of production, using the computational program GENES. The genotypes with yield higher than 28.33 bags of green coffee. ha<sup>-1</sup> were selected considering all the environments. The cultivars Catucaí Vermelho 36/6, Catucaí Amarelo 24/137, IBC Palma 1 and Paraíso MG H 419-1 presented adaptability in favorable environments ( $\beta_1 > 1$ ). Only the first cultivar presented high stability ( $S^2 = 0$ ). However the other cultivars were not discarded, because a high coefficient of determination ( $R^2 > 70\%$ ) was found in this case. The cultivars Ouro Verde IAC H 5010-5 and IBC Palma 2 presented adaptability in unfavorable environment ( $\beta_1 < 1$ ) and the last cultivar presented high stability ( $S^2 = 0$ ). The cultivars Sabiá 708, Catucaí Vermelho IAC 15, H514, Siriema 842 and Tupi IAC 1669-33, presented high adaptability, but low stability ( $S^2 > 0$ ). The line H518 and the cultivar Oeiras MG 6851 were classified as ideal for organic systems, because they presented high yield and high adaptability ( $\beta_1 = 1$ ) and high stability or predictability ( $S^2 = 0$ ). The authors thank FAPEMIG for the research grant.

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## SCALING-UP GAS EXCHANGES FROM LEAF TO ENTIRE COFFEE PLANT AND TO AGROFORESTRY PLOT, USING A COMBINATION OF LEAF CHAMBER, PLANT CHAMBER, EDDY COVARIANCE AND A SPATIALLY-EXPLICIT PLOT MODEL (MAESTRA) IN COSTA RICA

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Coffee-based agroforestry systems display two heterogeneous plant layers (shade tree and coffee), both discontinuous, uneven-aged and submitted to sequential pruning. Modeling the light interception by shade and coffee trees is a promising option to evaluate different scenarios and select some management alternatives. Due to the spatial and temporal complexity of the agroforestry system, we hypothesized that a spatially explicit (individual-centered) process model such as MAESTRA (Medlyn, 2004) was suitable to simulate light interactions, transpiration and photosynthesis. To our knowledge, MAESTRA has not been tested yet in agroforestry applications. MAESTRA was parameterized according to field inventories and other structural measurements (leaf area per tree, leaf angles, etc.), and the photosynthesis submodel was parameterized using leaf scale gas exchange measurements. The simulations of absorbed radiation (APAR) and photosynthesis were verified using direct measurements at plant (whole-plant chamber) and plot (eddy covariance) scales.

The experiment took place in Costa Rica within the Coffee-Flux<sup>1</sup> collaborative platform (Gomez-Delgado et al, 2011). The studied coffee plantation (*Coffea arabica* cv. cattura) was grown under low density, free-growing, *Erythrina poepigiana* shade trees. Coffee was pruned selectively, which resulted in an uneven-aged population of resprouts (1 to 6 years old). The main results are:

- 1) a successful validation of absorbed radiation (APAR), transpiration (T) and photosynthesis (GPP) simulated by MAESTRA at the scale of coffee plants with measurements performed *in situ* using a transient-state whole tree chamber;
- 2) a successful validation of modeled APAR, T and GPP at plot scale with *in situ* eddy-covariance measurements;
- 3) a comparison of plot APAR and GPP under different realistic scenarios, after varying shade trees densities, and pruning practices for coffee.

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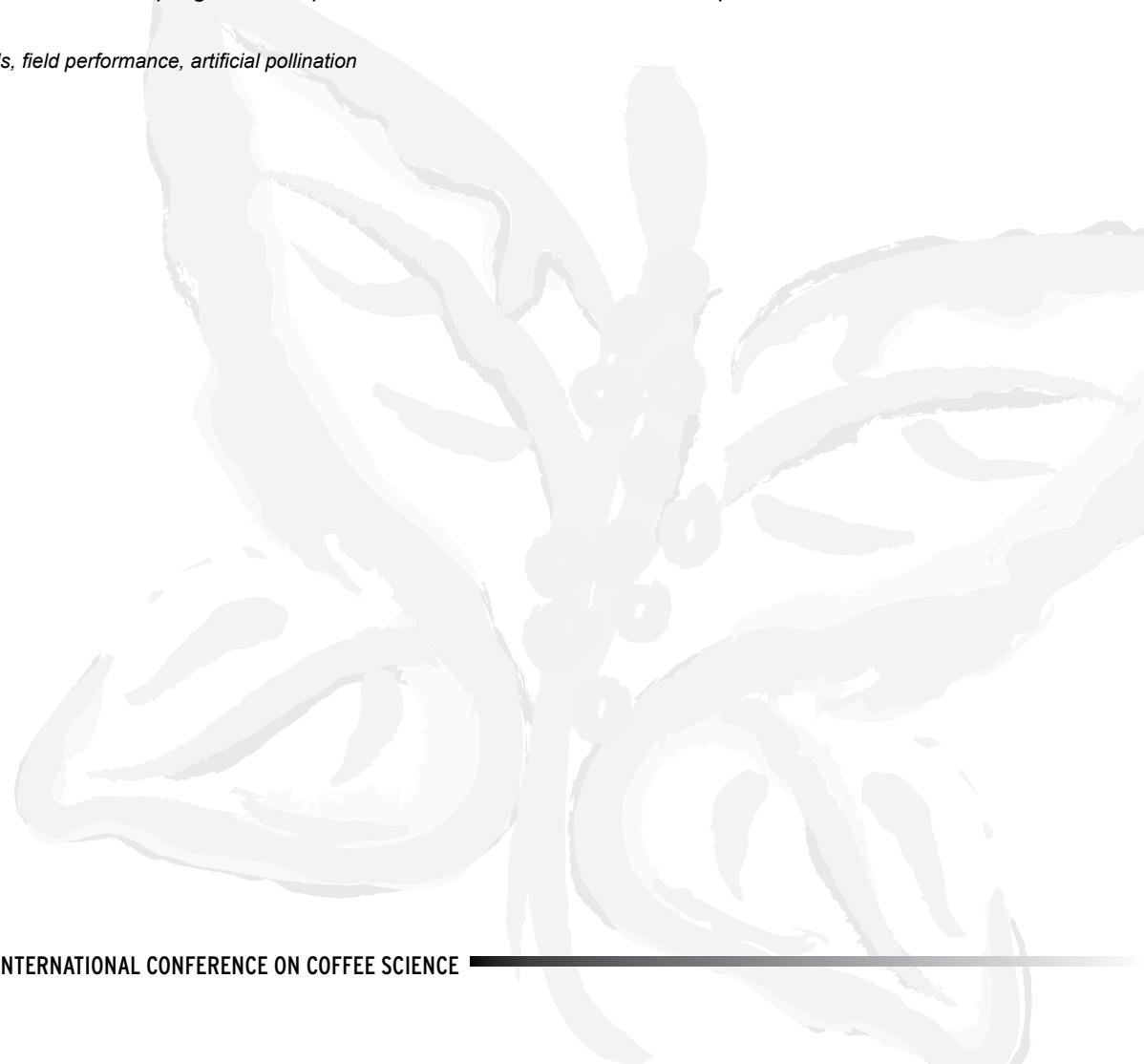
Medlyn, B., 2004. A MAESTRO Retrospective. In: M. Mencuccini, J. Moncrieff, K. McNaughton and J. Grace (Editors), Forests at the Land-Atmosphere Interface. CABI Publishing.

<sup>1</sup> Coffee-Flux platform: <http://www5.montpellier.inra.fr/ecosols/Recherche/Les-projets/CoffeeFlux>

**PA 298****PERFORMANCE OF TANZANIAN COMPACT COFFEE VARIETIES  
DERIVED FROM HYBRID SEEDS IN FARMERS' FIELDS****MTENGA, Damian\*, KILAMBO, Deusdedit\*, NGOMUO, Robert\* and TERI, James\***

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Tanzania has made appreciable progress in developing outstanding Arabica coffee hybrids that combine resistance to the two major diseases, coffee berry disease (CBD) and coffee leaf rust (CLR) with high yields and good beverage quality. The challenge now is the accelerated multiplication and distribution of these hybrid varieties for the necessary massive replanting programme with these improved varieties. TaCRI has perfected two vegetative methods – clonal multiplication and grafting – for the accelerated multiplication of these hybrids. Nevertheless, the high demand for seedlings cannot be met. TaCRI is now experimenting with the production of hybrid seeds of compact Arabica varieties as a more efficient technique of producing seedlings to meet the high demand as a complementary method. The complimentary method is multiplication of these varieties through production of hybrid seed . This is achieved by artificial manual pollination of preselected parent trees from the genotypes which meet all the pre-set selection criteria. Taking this into consideration, a new programme involving compact hybrid varieties was initiated with the aim of contributing towards the main task of making enough materials of improved varieties available to growers through the use of compact varieties hybrid seed. This programme was initiated in 2008 and currently the seed lots distributed to farmers fields are at the second year of production. The progress and performance of these materials is reported in this work.

*Key words: coffee hybrid seeds, field performance, artificial pollination*

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ORGANIC COFFEE PRODUCTION MODEL FOR ANALYSIS  
OF THE ECONOMIC AND ENERGETIC EFFICIENCY IN  
THE SOUTH REGION OF MINAS GERAIS STATE**TURCO, Patrícia H. N.<sup>1</sup>; ESPERANCINI, Maura S. T.<sup>2</sup>, BILSKA, Flavia, M. M.<sup>3</sup> and BUENO, Osmar C.<sup>4</sup>.**<sup>1</sup>Apta Regional/APTA, Campinas, Brazil, <sup>2</sup>Unesp, Botucatu, Brazil, <sup>3</sup>IAC/APTA, Campinas, Brazil and <sup>4</sup>Unesp, Botucatu, Brazil

The coffee growing has been through a deep restructuring in the past few decades, with significant changes in the farming practices. Due to the emergence of these innovative changes in production systems, the search for greater competitiveness involved improving quality, reducing costs and increasing mechanization. Since these factors involve investments and changes in traditional practices used, it is natural that there are questions about the technical and economic efficiency when considering the peculiar characteristics of a given producing region. Among the existing systems in the coffee culture, organic production is an alternative that aims the competitiveness, directly linked to the integration of production methods, minimizing costs of supplies by the use of waste and manure and the recycling of nutrients and organic matter. The cultivation of organic coffee can provide higher incomes to suit production requirements to the characteristics required for certain niche of markets. The objective of this study was to estimate the efficiency (both economic and energetic) of organic coffee production systems, making use of production costs and gross income, respectively, as economic *input* and *output*, the conversion of raw materials used in energy units, as well as the production of processed organic coffee beans, respectively, as energetic input and output. For the development of the study, outlined a system of production from survey data, reported by a sample of producers in different stages of production, which enabled the development of a matrix of technical coefficients average. The sampling adapted in the research was intentional and not probabilistic, seeking to select properties in which the culture of coffee is the main course of income. We interviewed nine producers in three counties in the South of Minas Gerais, which systematically make notes of the costs of culture. The results showed that the Equivalent Annual Gross Revenue and Equivalent Annual Cost were R\$4.926,95.ha<sup>-1</sup> e R\$4.084,09.ha<sup>-1</sup>, respectively. These results indicate that if revenues occurred throughout the year, farmers would get R\$5.012,16.ha<sup>-1</sup> and, similarly, if the costs were spread over the duration of culture, the producers would have an outlay of R\$4.084,09.ha<sup>-1</sup>. Applying the estimates to the equation of economic efficiency achieved the result of 1,21 is found, indicating that the gross revenue exceeds operating costs by 21% indicating an economically efficient system. In energy analysis, the results indicate that the systems have positive energy balances, with an energy yield of 637.697MJ . ha<sup>-1</sup> and the energy used to produce organic coffee amounted to 112.998 MJ. ha<sup>-1</sup> for 20 years considered the culture, indicating that the system was energy efficient. The biggest energy expenditures in the deployment and conduct of that crop were the biological source. In the production phase, the direct energy source fossil was superior to system.

Keywords: organic coffee; economic efficiency; energetic efficiency; production system.

**PA 300**

**ARABICA SELECTIONS WITH *Coffea eugeniooides*  
AND *C. canephora* INTROGRESSIONS FOR  
RONDÔNIA STATE IN BRAZILIAN AMAZON**

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The 80 years old ongoing coffee genetics program of Instituto Agronômico is largely based on exploitation of extensive germplasm resources of species, hybrids and derivatives. Likewise, a breeding project has been attempted to introgress quality traits of *Coffea eugeniooides*, the evolutionary female *C. arabica* species genitor into cv. Obatã, an inbred *C. arabica* cultivar bearer of lateness and rust resistance genes of *C. canephora*, the male *C. arabica* genitor counterpart. At high latitudes Obatã has performed well in hot climates under irrigated conditions. Among 126 Obatã backcross hybrids ( $BC_2$ ) with *C. arabica* x (*C. eugeniooides* 4n x *C. arabica*) studied several years in Campinas as to stature, vigor, yield, maturation, bean characteristics and beverage profile, 24 were additionally selected for the eugeniooides very late ripening, desirable by a cultivar for the tropical conditions of Rondônia State in the Amazon region of Brazil as a strategy to escape from rainy season during harvest. There, robustas thrive and arabicas are no longer grown due to a history of poor crops of low quality beans. Three  $F_3$  lines of Catuaí x Glaucia were also further selected for lateness. Glaucia is an Ethiopian accession that in Campinas ripens latter than Catuaí, a widely planted late cultivar. In addition, 11  $F_2$  arabusta populations were also studied, been one of *C. arabica* cv. Ibairi x *C. canephora* 4n, one of its reciprocal cross and 9 of Obatã x *C. canephora* 4n. Ripening check cultivars were represented by two very late Obatã lines, late Catuaí Vermelho and Catuaí Amarelo, medium two Paraíso lines and Topázio and by early Oeiras and Bourbon Amarelo. Replicated plots were set up in Ouro Preto do Oeste (Lat 10°45'S, Long 62°15'W, Alt 300m, Temp 25°C, Rainfall 2000mm, Aw Köppen). Vigor and general plant characteristics were observed during growth seasons, yields recorded for three years and cup quality evaluated in the second crop. As expected, greater variability was observed among such genetically diverse lines assayed and much less among individuals within them, except arabustas. Control cultivars showed all medium to early ripening and except one Obatã confirmed the known poor performance, yielding the equivalent of 10 to 24 clean 60 kg bags/ha, global quality 1 to 3 (out of 5), SCAA scores 40 to 62. Obatã lines yielded 25-32 bags/ha, global quality 2-3, SCAA scores 56-58. Unexpectedly by the results of sister populations grown in Campinas,  $F_2$  arabustas displayed scanty berry set though most had quite luxuriant foliage and pollinators were abundant. No one was selected for further investigations on grain characteristics and rooting ability.  $F_4$  Catuaí x Glaucia lines did not come up late, yielded or cup tested well, with 15 to 26 bags/ha, global cup scores 2, SCAA 52-56. Nevertheless, seven uniform ripening plants were selected for progeny tests. The 24  $F_2$  BC<sub>2</sub> Obatã x *C. eugeniooides* backcrosses were the foremost promising. Despite variable, most lines were remarkably late, several with impressive yields up to 45 bags/ha, global quality up to 4 and SCAA scores up to 80. Ninety-seven  $F_3$  BC<sub>2</sub> phenotypically selected that traced back to 20 selected late Obatã BC<sub>2</sub> were advanced and the two profuse crops of this ensuing generation displayed 33 progenies with delay in ripening of 3-4 weeks, attesting the adequacy of germplasm choice and selection procedures. Late and very late  $F_4$  BC<sub>2</sub> selections will be tried up also in neighboring Acre State. Hopefully they represent the forerunners of arabicas return to Rondonia.

## PA 301

HISTOLOGICAL CHARACTERIZATION OF RESISTANCE TO  
*Meloidogyne* spp. IN CONILON COFFEES

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Root-knot nematodes (RKN), *Meloidogyne* spp. cause major economic impact on coffee production in Brazil. Although *Coffea canephora* is a source of resistant genes to *Meloidogyne* spp., there are no histological studies comparing mechanisms of resistance of susceptible and resistant coffee plants. Two clones of Robusta coffee plants, 14 and 22, were selected as respectively resistant and susceptible to *M. incognita* and *M. paranaensis*. Roots of both clones plus *C. arabica* (Catuaí IAC 81, a susceptible standard pattern) were fixed according to methods of Byrd (1983) and Pegard et al. (2005). The reaction of different clones to the two nematode species studied was similar. Clone 14 showed hypersensitivity reaction (HR) between the 4th and 8th days after inoculation (DAI) in the root cortex, leading to cell death, which prevented the nematode development. At 12 DAI, giant cells formed in the vascular cylinder besides normally developing J3/J4. From the 32th to 45th DAI, HR was observed along with dead cells around females and completely degenerated giant cells. During this period, some fully-grown females even developed early stages of ovaries, although they did not produce eggs. In the susceptible clones, 22 and Catuaí IAC 81, well-formed giant cells and adult females appeared between the 38th and 45th DAI, also with egg production. Plants used in the histopathological studies were replanted and evaluated to corroborate to previous results on resistance/susceptibility. Three hundred DAI, plants were evaluated and the responses obtained in previous studies were confirmed. These results provide bases for further gene expression studies, which will profoundly examine resistance to RKN at molecular the level.

## PA 302

PURSUING GREEN COFFEE GEOGRAPHIC ORIGIN  
DISCRIMINATION THROUGH RELATIONS BETWEEN ISOTOPES  
AND ENVIRONMENTAL FACTORS (ISOGEOCOFFEE PROJECT)

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In the present work, several spectroscopic techniques were applied for the differentiation of different types of coffee and of their geographical origin. In a first approach, a study on the application of Raman spectroscopy to the differentiation of coffee type (*Arabica* versus *Robusta*) was developed based on the determination of kahweol content. Isotope Ratio Mass Spectrometry (IRMS) was then applied for the determination of the isotopic composition of carbon (C), nitrogen (N) and oxygen (O) of the green coffee bean, allowing coffee differentiation at continental level. Subsequently, IRMS was combined with Inductively Coupled Plasma Mass

Spectrometry (ICP-MS) to determine the isotopic composition of strontium (Sr) in the coffee bean. The results obtained demonstrated that the isotope ratios of Sr and O of the coffee bean are a promising tool for its traceability, as these elements reflect the local geology and hydrology. In order to expand the understanding of how environmental factors determine the isotopic composition of the different elements on the green coffee bean, further research was developed focusing the region of Hawaii. The results allowed for the differentiation of the different coffee-producing regions of Hawaii. In addition, IRMS was also applied to measure the oxygen isotopic composition of the caffeine molecule ( $\delta^{18}\text{O}_{\text{caff}}$ ), previously extracted from the green coffee bean. O isotopes of caffeine molecule originate from the metabolic water of plant tissues, and accordingly results showed that this organic specific compound may be relevant for studies on the coffee plant ecophysiology.

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**PA 303**

### **MANAGEMENT EFFECTS ON PHOTOSYNTHETIC CAPACITY AND LEAF LEVEL NUTRITION IN TROPICAL SHADE AGROFORESTRY SYSTEMS: THE CASE OF COFFEE IN COSTA RICA**

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Growing concern regarding the long-term environmental sustainability of intensive *C. arabica* (coffee) production is increasing the re-evaluation of more sustainable methods of coffee production. Agroforestry coffee production methods present one potentially viable alternative, but further research on interspecies shade and nutrient interactions particularly at the leaf level is needed to inform efficient and effective system design. A study was undertaken to compare the adaptation of resource acquisition strategies of 10 year old coffee plants under full sun and legume (*Erythrina* sp. and *Chloroleucon* sp.) shaded conditions in combination with organic and conventional fertilization regimes at a Costa Rican experimental research site. Shade levels below biannually pruned, conventionally fertilized *Erythrina* elicited the strongest adaptive response in coffee as evidenced by improved photosynthetic performance at both high ( $A_{\max} = 4.632 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ;  $P = 0.0185$ ) and low (light compensation point =  $17 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ) light levels relative to coffee grown beneath *Chloroleucon* or full sun. These coffee plants associated with *Erythrina* were also found to have a higher average leaf area ( $39.29 \text{ cm}^2$ ;  $P = 0.0070$ ), and dry mass ( $0.210 \text{ g}$ ;  $P = 0.0570$ ) than any of the other treatment combinations tested. Organic fertilization was found to significantly improve soil surface available P levels in comparison to conventional fertilization ( $P = 0.0300$ ) regardless of shade species, though conventional fertilization elicited a stronger shade response in the coffee plants. Based on study findings, shade mechanisms appear to be the most important drivers of aboveground coffee adaptation in coffee agroforestry systems, though proper soil nutrient management in low nutrient environments also appears to augment coffee response to microclimate conditions.

**PA 304****COFFEE SUSTAINABILITY, THE VIEW FROM A ROASTER**

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Consumers in Western markets look at sustainability as a factor in making their choices. However, roasters, recognise their responsibilities both to farming communities and consumers – who rightly expect us to act on their behalf, not delegate the issue to consumer demand. This has driven substantial business engagement among coffee roasters in the past decade, in particular in terms of sourcing standards and agriculture practices. The talk will first review the status of life-cycle analysis of the carbon footprint of coffee product formats (roast & ground, soluble and on-demand systems) as a tool to understand impacts and measure progress: the focus will be on both the impact of consumer use as well as primary production and agronomy. For example, whilst packaging is often a small component it has a much higher relevance placed on it by consumers. Gaps in our carbon knowledge and actions needed to fill them will be highlighted. The talk will then take a wider look at coffee sustainability from a large roaster perspective. Today many small and large coffee companies are using sustainability claims in the market mostly through agriculture certification. They also leverage efforts on other areas such as energy use and packaging. Indeed Kraftfoods Europe have announced a baseline standard of all their coffee being 4c verified by 2015 we are heavily engaged in building 4c verification and we continue to work with Rainforest Alliance to scale-up certification. In general, for the coffee sector, our success in protecting the pleasure of coffee for future generations requires creation of a trusted value chain and transparent collaboration of agents within in. What is most important is that our commitment to sustainable coffee production standards will result in increased investment in farming communities.

**PA 305****RESTRUCTURED SAMPLING PLAN ENABLES THE CHARACTERIZATION OF MORE VIRULENCE GENES OF *HEMILEIA VASTATRIX* IN KENYA**

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Arabica coffee was introduced in Kenya about 1900. The crop spread across the country both as commercial cultivation and germplasm conservation plots. The first report of coffee leaf rust (*Hemileia vastatrix* Berk. & Br.) in the country was made in 1912 and breeding for resistance against the disease has been a priority. In addition to conventional *Coffea arabica* L. varieties, derivatives of Timor Hybrid (HTDs) that are natural hybrids between *C. arabica* and *C. canephora* Pierre ex Froehner have been introduced into the country and used in breeding programmes since early 1960s. The HTDs received major genes responsible for rust resistance ( $S_H$ <sub>6</sub>,  $S_H$ <sub>7</sub>,  $S_H$ <sub>8</sub>,  $S_H$ <sub>9</sub> and others not yet identified) present in *C. canephora* germplasm introgressed into *C. arabica*. New virulence genes and/or races of the pathogen have not been reported among rust samples collected from the country since 1977, when four virulence genes (v 2, 3, 4 and 5) were identified. This evidenced the urgent need of redesigning the survey strategy in order to increase the chances of detecting new races of the

pathogen. Sampling was therefore conducted targeting coffee germplasm conservation plots, breeding fields and commercial farms planted with mixed coffee varieties. The samples were characterised at the Coffee Rusts Research Centre (CIFC), Portugal, and the results revealed three new virulence genes ( $v_1$ ,  $v_7$  and  $v_8$ ) with the possibility of a fourth one ( $v_9$ ). The virulence genes  $v_7$ ,  $v_8$  and  $v_9$  are able to overcome the resistance genes derived from HDTs and this presents a threat to the resistant varieties being developed. This presentation discusses the outlook possible implications of such a status.

**PA 306****INTROGRESSION OF THE RUST RESISTANCE GENE  $S_{H3}$  INTO COLOMBIAN ELITE CATIMORS THROUGH A MARKER ASSISTED SELECTION STRATEGY****HERRERA, Juan Carlos\*, HURTADO, Ifigenia, GONZALES, Laura, CORTINA, Hernando**

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Experience on genetic control of phytopathological fungus in different crops including coffee trees, shows that extensive use (in time and space) of resistant varieties raise the possibilities of emergence of new races more and more virulent. Since liberation of the Colombia variety in 1985 and then the Castillo® variety and its regional components in 2005, progressive occurrence of plants with presence of rust symptoms suggest the generation of new *Hemileia vastatrix* races compatible with resistance genes (R genes) carried by these Catimor derivatives. Introgression into Colombian varieties of a new gene such as  $S_{H3}$  would facilitate creation of genotypes carrying new combinations of R genes which will operate in the field as a genetic barrier against predominant rust races. Recent identification of molecular markers linked to the  $S_{H3}$  gene issued from *C. liberica* (Mahé et al, 2008; Lashermes et al., 2010) have opened the possibility of real implementation of an strategy of marker assisted selection (MAS) in coffee breeding programs around the world. The aim of this work was to develop advanced lines (i.e. F4) recombining the  $S_{H3}$  along with the R genes already present in the Colombian elite genotypes and derived from the Timor Hybrid (i.e.  $S_{H6}$  to  $S_{H9}$ ). To do that, the Coffee Breeding Program of Cenicafé starts in 2010 a wide cross pollination program involving 44 élite Catimors derived from different accession of the Timor Hybrid (i.e. CIFC-1343, CIFC-832 and CIFC-2252) and some selected Arabica genotypes present in the Colombian gene bank and known as be introgressed by the  $S_{H3}$  gene. During first part of this project more than 130 crosses have been produced, giving as result almost 500 F1 hybrid plants. Using a MAS strategy, almost 250 F1 seedlings carrying the  $S_{H3}$  gene have been identified and will be transferred to the field in order to obtain F2 seeds. Once planted, the F2 families will be evaluated and selection for desirable types involving high rust resistance and vigor, elevated productivity and good bean size will be done. The F3 families derived from best F2 plants will finally be evaluated by regional adaptability and high cup quality in order to select the best F3-F4 lines. These genotypes will be used as part of composite varieties which have been the central point of the strategy used by Colombia in order to achieve a more durable resistance by maintaining a high genetic diversity against this disease.

## PA 307

## RELATIVE INFLUENCE OF PLOT AND LANDSCAPE SCALE FACTORS ON COFFEE BERRY BORER ABUNDANCE: A VARIATION PARTITIONING HIERARCHICAL APPROACH

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Pests and diseases are under the influence of multiple factors that act at plot and landscape level. Romero *et al.* (2011) demonstrated that the coffee berry borer (*Hypothenemus hampei*; Coleoptera: Curculionidae) abundance in coffee plots was positively correlated to the proportion of coffee area in the landscape, possibly because coffee berry borer survival was improved during postharvest period in landscapes with more resources. On the contrary, proportion of other land uses in the landscape, as forest, pasture and sugar cane, were negatively correlated to the pest abundance. This raises the question of the importance of landscape effects on the pest, compared to known plot scale effects on which control practices are based. We used data from Romero *et al.* (2011) where 50 geo-referenced coffee plots, from Turrialba, Costa Rica, were characterized for their management, environmental, plant status and landscape attributes, as well as for the coffee berry borer abundance. We quantified the relative influence of local factors, landscape context and spatial distance between plots on coffee berry borer by using variation partitioning techniques and generalized hierarchical models (Legendre, 2008). Our results indicate that environmental and landscape variables explain the highest proportion of coffee borer abundance variation (individual fractions: 22% and 17% respectively). However, when assessing the unique contribution of each variable, the number of remaining infested coffee fruits per tree after harvest was the most important variable with 22% of the coffee berry borer abundance variation explained, followed by the number of fruiting nodes (16%), altitude (associated to temperature, 13%), and in a lesser degree, shade type (11%), spatial dependence between plots (9%) and proportion of pasture in a 400 m radius (7%). Spatial dependence indicates that pairs of coffee plantations at a distance smaller than 450 m have similar coffee berry borer infestations, suggesting exchanges of populations between coffee plots under this distance. Our results indicate that picking infested coffee fruits remaining after harvest is the most important cropping practice for the control of coffee berry borer. However landscape context attributes explain coffee berry borer abundance, their low contribution to the total variation of the pest abundance suggests that control practices at landscape scale should only have slight effects on coffee berry borer abundance.

Romero, A., Cruz, H., De Melo, E., DeClerck, F., Avelino, J., 2011. Landscape context and plot incidence of coffee rust (*Hemileia vastatrix*), coffee berry borer (*Hypothenemus hampei*) and the root-knot nematodes *Meloidogyne* spp. in Costa Rica. 23rd International Conference on Coffee Science. ASIC, Bali, Indonesia, pp. 999-1002.

Legendre, P., 2008. Studying beta diversity: ecological variation partitioning by multiple regression and canonical analysis. Journal of Plant Ecology 31:976–981.

## PA 308

## ENVIRONMENTAL PERFORMANCE OF CERTIFIED COFFEE FARMS IN NICARAGUA

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Sustainable certification of coffee has grown considerably over the past decade aiming to assure consumers that farms meet a range of social and environmental conditions. However the question remains "How effective are the certifications at discriminating between farms with different environmental management practices

and conditions?" To address this question 294 coffee farms were surveyed in the main coffee growing region of Nicaragua divided between 5 certifications (C.A.F.E. Practices, Fairtrade, Organic, Rainforest and Utz certified) and conventional farms. The survey was conducted using the COSA (Committee on Sustainability Assessment) methodology. Certifications varied in the average (and range) in farm size, and farm size also significantly affected some environmental characteristics. To control for this farm size was used as a co-variable. Where this was significant a regression tree was used to define different size categories and included in the analysis of variance to check for an interaction of farm size with certification. Variables that are scored (i.e. no continuous variables) were tested using principal components analysis. The characteristics of the shade, a primary environmental interest, had no significant difference in the density of trees but organic, Fairtrade and Utz had greater species richness (when normalized for farm size) and more tree strata (3 strata) than conventional (1 strata) or other certifications (2 strata), but these characteristics were also associated with small farms. Estimates of area eroded in the plantation was significantly lower for organic (4%) than other certifications and conventional (8-14%), and also had the highest ground cover – although not statistically significant, while in general certified farms were associated with application of soil conservation practices compared to conventional farms. Practices to manage water contamination were associated with Rainforest Alliance, C.A.F.E. Practices, and Utz certified farms (and larger farms), but not with Fairtrade, conventional or in general small farms. In general certifications were associated with different environmental characteristics, but these were also a function of the typical farm size being certified. Aspects in which certifications differentiated were not necessarily in line with the criteria of the certification, for example those with more developed shade do not have especially well developed criteria on shade.

**PA 309**

### **STRENGTHENING PRODUCER ORGANIZATIONS TO SPEED UP THE MULTIPLICATION OF IMPROVED HYBRID COFFEE VARIETIES IN TANZANIA**

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Recent progress in coffee research by the Tanzania Coffee Research Institute (TaCRI) has led to the release of 15 Arabica hybrid coffee varieties that are resistant to coffee berry disease (CBD) and coffee leaf rust (CLR) and 4 Robusta hybrid coffee varieties that are resistant to coffee wilt disease (CWD) that threaten both Arabica and Robusta coffee growers in the country. These improved varieties are the foundation for a coffee green revolution in Tanzania as they are high yielding, resistant to the major pests, have good cup quality and adapted to a wide range of environments. However, since they are hybrids their multiplication is through vegetative propagation. TaCRI has perfected two methods, clonal propagation and grafting for their multiplication, which go together with the provision of training courses to producer organizations to accelerate the multiplication of improved hybrid seedlings. Linkage has been established with over 600 nurseries of the improved hybrid varieties for both Arabica and Robusta coffee varieties scattered across the country which have the capacity of multiplying over 18 million seedlings per year. The decentralization of seedlings multiplication programme as well as participation of various stakeholders in the management of their own nurseries has resulted into increased number of seedlings multiplication for replanting programmes. This paper outlines the progress achieved in hybrid seedlings multiplication.

Key words: Producer organizations, Multiplication, Improved hybrids

**PA 310**

## **IDENTIFICATION OF THE VULNERABILITY OF COFFEE FARMERS' LIVELIHOODS AND DEVELOPMENT OF ADAPTATION STRATEGIES TO CLIMATE CHANGE IN MESOAMERICAN**

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According to the Intergovernmental Panel of Climate Change (IPCC) report, Mesoamerica is one of the regions that will suffer severe impacts from a progressively changing climate. Coffee production is the mainstay of thousands of families and the major contributor to the agricultural GDP of these countries, hence vulnerability assessments are of vital importance to identify adequate adaptation strategies. Nicaragua, El Salvador, Guatemala and Mexico were investigated in the present paper.

Vulnerability was defined considering three factors: exposure, sensitivity and adaptive capacity. Exposure was determined by modeling coffee production suitability (current and future) for the A2a emission scenario (business as usual) using twenty downscaled Global Circulation Models (GCM) in combination with Maxent and Ecocrop crop prediction software. Focus groups and an expert panel were used to develop indicators for sensitivity and adaptive capacity which were field validated by 558 semi-structured interviews with coffee households. Participatory workshops were carried out aiming at the development of prospective guidelines towards climate change adaptive capacity. Nine indicators were validated for sensitivity and eleven for adaptive capacity.

Through the combination of exposure with the indicators of sensitivity and adaptive capacity, vulnerability was identified for coffee producers in the four countries. High exposure was defined as suitability loss of coffee production by 2050. Coffee farms will lose suitability between 20-81% in El Salvador, 20-59% in Nicaragua, 24-47% in Guatemala, and 25-45% in Mexico. High sensitivity and low adaptive capacity were evaluated considering livelihood capitals, whereby coffee productivity level and post-harvest infrastructure were identified as the most determining indicators in all countries. Additionally, in Nicaragua and Mexico migration was identified as important. Furthermore, in Nicaragua, El Salvador and Guatemala, low access to technologies, education and organization level are very important. A common characteristic of all farmers was a high income dependency on coffee (50-55%), corn and beans (20-30%).

The families of the four countries identified the following adaptation strategies to climate change: Conservation and planning of sustainable management of the resources, diversification of crops in areas with coffee suitability loss, raise of the level of access to education, sensitization of key actors in conservation, organizational strengthening, capacitation through participatory action research and creation of financial credit programs. However, the analysis suggests that strategies must consider policies and the families' geographical location, and access to and availability of resources.

Key words: Vulnerability, livelihoods, climate change, exposure, sensitivity and adaptive capacity

PA 311

PARTICIPATORY BREEDING ON ARABICA COFFEE TO OBTAIN  
SUPERIOR LOCAL VARIETY IN ORDER TO SUPPORT SPECIALTY  
ORIGIN COFFEE DEVELOPMENT IN INDONESIA**HULUPI, Retno, NUGROHO, Dwi, MAWARDI, Surip and AMAN AL, Maisyir**

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A participatory breeding on Arabica coffee involving farmers and plant breeders to select superior of local variety(s) has been conducted at Gayo highland (Central Aceh, Northern Sumatra) and Kendenan Plateau (Enrekang, South Sulawesi). The aim of applying this method was to find out superior variety(s) of Arabica coffee having appropriate specific traits and adaptable to such location. Moreover it can be expected to accelerate the process of varieties adoption by local farmers. Collaboration between local farmers and coffee breeder in participatory breeding is also an important step to eliminate farmer's worry in adopting new national variety(s) released by the government whether suitable to their local conditions or not. Selection process was usually initiated by the farmer(s) based on high yielding performance by using their native experiences. The next step was conducted by plant breeder in cooperation with coffee farmers and other relevant scientists to evaluate more detail yielding capacity, agronomic traits, resistance to leaf rust and/or parasitic nematode as well as cup quality profile. Cup profile also evaluated by overseas professionals. Yielding ability was observed on its parent-offspring populations for 3 – 4 years. Selected candidate varieties were compared to commercial varieties (S 795 and Typica) at different farmer's sites for several years observations. The results showed as follows: (1) Two selected varieties namely Gayo 1 and Gayo 2 already been released by Minister of Agriculture for commercial planting at Gayo highland. The two varieties perform excellent cup profile with high yielding ability (2 tones/ha) and tolerant to leaf rust disease. (2) Observation over selected local variety at Kendenan Plateau namely Salongge variety performed lower yielding ability (below 1 ton/ha) and less stable yield over years as well as more heterogenous population in it's offspring than that of existing released varieties planted at the same location. (3) Participatory breeding approach in form of collaboration between farmers and coffee breeders is able to accelerate in developing local specific varieties.

Keywords: Participatory breeding, arabica coffee, local variety, coffee specialty.

**PA 312****ENVIRONMENTAL AND SOCIAL STANDARDS AND QUALITY:  
CATALYST INGREDIENTS OF A DYNAMIC YOUNG COFFEE  
COOPERATIVE MOVEMENT IN NICARAGUA****HOCDÉ, H.\*, LE COQ, JF\*, MENDOZA, R.\*\*, HAGGAR, J..\*\*\* PREZA, M. \*\*\*\***

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In Nicaragua at the end of the 80's coffee exports were managed by the state. By 2010/2011 73 companies were exporting coffee of which 25 were cooperatives representing nearly 20,000 producers. Data from the Centre for Export Procedures reports a considerable increase in exports from cooperatives up from 10% in 2006/07 to 19% on 2010/2011. The cooperatives have the productive potential to export up to 22% of national production, but are financially limited in their ability to collect all the coffee from their members. In the last harvest the FOB prices from cooperative exports were 11% higher than for the two main multinational exporters.

The cooperative movement was launched from 1993 from a nucleus of second-tier cooperatives, which is diversifying with the development of a third generation and increased exporter capacity amongst 1st tier cooperatives. In this process of development the cooperatives found little support from national policies but developed on their own efforts supported by international cooperation. Their creation was with the aim of taking control of the export of coffee. This focussed on improving and assuring the quality of the coffee, and implementing individual and collective quality control procedures from the farm to the port.

Being protagonists and founders of the Fairtrade movement and the integration of organic certification for many members was fundamental to the establishment of the cooperatives. Later they have diversified into other sustainable markets with Rainforest Alliance, C.A.F.E. Practices and Utz certified. Although always quality has been more important than the certification to the markets. Above all the cooperatives have sought to deal and sell directly to roasters.

The process has had many challenges. Including ensuring the balance of power and responsibility between the directors and managers of the cooperatives and their members; the competition with transnational owned exporters and an emerging group of large-scale producer-exporters, and comply with the quality and business acumen required to export directly to roasters. Having achieved a commercial capacity, now the challenge is to build the productive capacity of the members, which require financing for producers to increase production but also pay for that production with increasing world prices, creating the need to manage substantial credit facilities.

Ultimately the sustainable environmental certification of the product is of lesser interest, than the development of a cooperative movement in reducing poverty and improving the livelihoods of producer families through the increasing demand for specialty coffee.

**PA 313****STRENGTHENING ARABICA COFFEE QUALITY  
BREEDING RESEARCH STRATEGY IN ETHIOPIA  
THROUGH OPTIMUM USE OF COFFEE TERROIR****BEKELE, G.<sup>1</sup>, BELLACHEW, B.<sup>2</sup>, AYANO, A., BENTI, T<sup>3</sup>.**

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Arabica coffee (*Coffea arabica* L.) breeding research strategy in Ethiopia has been under continuous modification since the inception of the program in late 1960 at the then Jimma Agricultural Research Station. The prevalence of coffee production and productivity problems, presence of diverse coffee gene pool,

contrasting coffee growing agro ecology, market demand, consumer preference, growth of speciality coffee industry, outbreak of new diseases and insect pest and expression of considerable genotype by environment interaction for economically important traits are some of the major driving forces, among others, behind the progressive adjustment of coffee research strategy in the country. Accordingly, a local landrace development program developed in 2002 was the recent advancement in coffee research strategy development which was widely applied in the country. This program has demonstrated remarkable results in effective use of local genetic diversity, maintaining the typical quality of each locality, avoiding adaptation problem and maintaining farmers' preference for local varieties. The current intension is to strengthen the application of this strategy or program with respect to quality improvement and profile mapping through optimal use of coffee *terroir*. The implication of *terroir* concept in quality improvement, development of coffee quality profile and mapping and promotion of origin based speciality coffee has been discussed in detail.

## PA 314

### **STATUS OF COFFEE RESEARCH IN ETHIOPIA: ACHIEVEMENTS, CHALLENGES AND PROSPECTS**

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The Jimma Research Center (JRC), which holds the national mandate of coordinating coffee research, had made appreciable endeavors in collecting and preserving different arabica coffee genetic resources (more than 6000 accessions) at various field genebanks for future research purposes. In effect, the national coffee research has contributed in safeguarding the coffee industry from the possible irreversible erosions due to the severe outbreak of coffee berry disease in the country. Coffee research has also played a crucial role for increasing coffee production and national export earnings. So far, a total of 37 arabica coffee varieties and full packages have been released for the major coffee growing areas of the country. However, the country is unable to fully exploit from the huge coffee potentials, among others, due to insufficient collective actions to disseminate the available technologies. The coffee research has designed location-based research and development strategy for sustainable production of marketing-oriented quality profile, ensuring competitiveness in the international market. This would also contribute towards efficient management and use of coffee genetic and environmental diversities and improve the livelihoods of the rural communities and coffee producers. However, the rapid expansion of improved coffee technologies is constrained by several factors including finance, facilities, trained man power and quality inputs, among others. Above all, there is acute shortage of suitable coffee seeds and seedlings in the country. To this end, the JRC has made concerted efforts in production of foundation and certified coffee seeds and seedlings using various approaches, including seeds, cuttings and tissue culture approaches. The center has also taken the initiative of multiplication and distribution of specialty coffee varieties with the aims to establish sustainable specialty coffee seed system at each locality. This, however, calls for strong government supports and collaborations of national and international specialty coffee partners. Likewise, optimum agronomic, processing and modern marketing system should be widely adopted across the country to realize the targeted national plan from the coffee commodity. This demands permanent research-extension and stakeholder linkages and technologically assisted R & D options towards promoting commercialization-oriented coffee production and marketing systems.

## PA 315

PEST STATUS, DAMAGE AND HOST PLANT UTILIZATION OF THE BLACK COFFEE TWIG BORER (BCTB), *XYLOSANDRUS COMPACTUS* (EICHHOFF) (COLEOPTERA: CURCULIONIDAE) IN UGANDA

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The Black Coffee Twig Borer (BCTB), *Xylosandrus compactus* (Eichhoff) is a new but rapidly spreading pest of coffee but also surviving on other plant species. However, knowledge of its pest status, damage and host plant utilization in Uganda is limited. We conducted a survey on 250 households in the 5 major coffee growing regions of Uganda. At farm level, 12 coffee trees were observed for BCTB infestation. In addition, host plant utilization by BCTB was determined through farmer interviews and direct searching by researchers. BCTB was observed in all the sampled districts in central and at least 50% of the districts in southwestern region but not in West Nile, Mt. Elgon and northern regions. Infestation was higher in central (58.0%) than southwestern region (22.1%). At district level, infestation was highest in Mukono and Luwero (100%) followed by Bundibugyo (62.5%) and lowest in Mpigi (10%). Similarly, the percentage of trees attacked (incidence) and percentage of bored twigs (damage) were highest in Mukono (91.7 and 13.6% respectively) followed by Luwero (73.3 and 5.2% respectively) and Bundibugyo (44.8 and 4.8% respectively). Note that in Mubende and Mpigi, incidence and damage were 0% because BCTB was not observed in the transect but present on other coffee plants on the farms. The study identified and documented at least 30 host plant species for the twig borer including important food crops, commercial crops, forest and shade trees. In conclusion, the pest is rapidly spreading away from its place of origin and epicenter to new infestation areas and poses a big threat to coffee production and other host plant species in Uganda. Thus, comprehensive mitigation measures should put in place in order to prevent it from spreading to new areas and also to minimize its impact on coffee production within the already affected areas.

**Key words:** Black coffee twig borer, coffee cropping systems, damage, host plant species, incidence, infestation, Uganda, *Xylosandrus compactus*

## PU 600

IMPACTS OF NANOTECHNOLOGY IN  
THE BRAZILIAN COFFEE INDUSTRY**BLISKA, Flávia\*; VEGRO, Celso\*\*; MARTINS, Paulo\*\*; FACHINI, Cristina\*\*\***

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Nanoscience and nanotechnology have been appointed as the basis for a new revolution, but this time not only industrial, but a revolution in the nature of the human civilization itself. The development of new materials, as well as changes in manufacturing platforms, will result in social, environmental and economic ever experienced. The exponential growth of investments in research in this area, especially in the central countries, shows the immense interest in the use of those technologies, although it is still only an infant sector. On the other hand, growing distrust of many sectors of public opinion, which tend, as has happened with genetically modified foods, to reject these innovations with a character so disruptor. Therefore, it is important to develop research to provide the public debate on nanotechnology, with urgency, in order to engage segments of society that, unlike what happened with biotechnology, there is a broader understanding of the likely benefits and risks of technologies derived from nanoscience, going beyond the information presented by the media, which are guided generally by the sensationalism that the subject entails. The objective of this research is to identify the social, environmental and economic impacts, actual and potential, arising from the introduction of nanotechnology in the coffee industry in Brazil. The purpose of the use of indicators of social and environmental impacts were: to establish a reference for public policies on employment, labor, income, education, professional training and health, support the regional development programs; indicate corrective and preventive actions. Interviews were conducted in different segments and industry sectors, using the Delphi technique. The social, environmental and economic results of the introduction of nanotechnology were grouped into three sets: a) processes, services and nanotechnology products already adopted b) processes, services and products in nanotechnology that are being studied and developed, c) potential processes, products and services in nanotechnology. Preliminary remarks points that the discussions based on products already developed and those that are being studied are more concerned about the "economic impacts" once Brazilian public opinion are not aware on the theme. In this case, the federal regulation plays an important role on the process. The point is that experts on regulation still do not have a consensus opinion on the subject.

## PU 601

ANALYSES OF THE COMPANY DELTA CAFÉS' STRATEGIES  
IN THE SEGMENT OF SINGLE CUP COFFEE: INSIGHTS FOR  
BRAZILIAN COFFEE ROASTING INDUSTRY**RIBEIRO, Felipe B.\*; GONÇALVES, Larissa, C. S. V.\*; ABREU, Pedro H.\*; GOMES, Priscila F.\*; ABREU, Giselle F.\*; SILVA, Eduardo C.\*; CASTRO JUNIOR, Luiz G.\***

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Brazil is the largest producer and exporter of coffee, besides being the second largest consumer of the drink. However, the Brazilian coffee roasting in 2011 showed a deficit in trade balance of roast and ground coffee. The value of imports of the product was higher than those of exports. The country has had difficulty leveraging its exports of roast and ground coffee, but this is only one explanation for the deficit. The main reason is the explosion of imports of coffee capsules for machines single-cup coffee. These capsules have more value than the traditional roast and ground coffee. To reduce the trade deficit and exploit the enormous potential that the market for single-cup coffee has, it is necessary that Brazilian roaster invest in this segment. However, companies wishing to invest in this sector will face competition from large multinationals already established. Despite the barriers to entry, it is possible that domestic companies participating in this market and even surpass their competitors. This is the case of Portuguese Delta Cafés, that despite the smaller size, it is on par with the multinational active in your country. This example is of great interest for the Brazilian coffee roasting, as the strategy used by the Delta can be adapted to the reality of the country. On this basis, it designed a

case study of Delta Cafés and its business strategy in the segment of single-cup coffee. The aim is to base future action strategies of national roasters in this segment. Among the obtained information, one of the most interesting is the fact that, besides the Delta is a family run company, totally Portuguese, development and manufacture of its machines and coffee capsules is all done on Portuguese soil, with national companies. This indicates that the technological barriers to entry in coffee capsules are relatively low. The case study also showed that although not a pioneer in the segment of single-cup coffee, Delta managed to take the lead in this niche, surpassing its rival multinational. The obtained information from this study may guide the development of a strategy for the Brazilian coffee roasters, so that they can compete in promising segment of single-cup coffee. The presence of Brazilian companies in this sector is of great interest to the country, since it can limit the volume of imports. Moreover, the strengthening of local industry rises the demand for quality coffee and the gains of the sector, with benefits for the entire production chain.

## PU 602

### GROWING STRATEGY OF COFFEE SHOP CHAINS IN THE SCENARIO OF FINANCIAL CRISIS

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The great coffee shop chains have been using a lot of strategy to increase its part in the market, mitigating factors that happened after the economic crisis of 2008. One of these factors is the reduction of the expenses with luxury estates, like the special coffees consumption. These strategies have been irritated the competition in the sector, but they contribute for the growing of it promoting the increase of special coffee's intake. This research work aimed to identify strategies that large networks of coffee shops use to expand their business in the current moment, which is economically unfavorable. From the concept of Competitive Intelligence, we sought to better understand these strategies, in order to identify and monitor trends in the sector. For this study, the data were collected through the Internet, with a systematic monitoring of the key sector news over eight months, in august 2011 to march 2012. From this, the data were analyzed and grouped in order to better understand the changes underway. Some of the strategies identified and widely used by large outlet's network were:

- Use of different forms of marketing, varying according to cultural factors in each country and also the amount to be invested;
- Reforming of the interior of the shops to promote greater comfort to the customer, including offering free wireless internet;
- Diversification of the offered coffee as options for lighter roasting, new espresso-based drinks and new methods of preparation;
- Diversification of the offered products, such as snacks, beer, wine;
- Expansion into less saturated markets, as developing countries;
- New store formats, such as drive-thrus, kiosk and mobile shops.

These strategies highlight the commitment of the coffee shop sector to continue to grow, even at a critical moment for the world economy. This should be seen as something positive for the entire production chain of the coffee business. Coffee shops are at the forefront of encouraging the intake of coffee. They stimulate consumption among young people, ensuring the consumer base for the future and increase the demand for specialty coffees.

**PU 603**

**INNOVATION AS CONDITIONING FOR GROWING  
COFFEE INTAKE IN THE WORLD**

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We know the effects of urban development and the increase in per capita income on the consumption of coffee. Developed countries like USA, Japan, Germany, Finland, Norway and others, present levels of consumption of this drink far superior to that observed in developing nations. Furthermore, the coffee is a valuable source of energy for the modern worker. However, there is another crucial factor for the success of coffee: technological innovation in the forms of preparation and consumption of this product. The aim of this paper is to demonstrate, through a historical review, the role of innovation on the way that coffee is consumed in the world. The hypothesis presented is that much of the world consumption of this drink is due to a plenty of innovations developed by entrepreneurs and companies in the sector since the late nineteenth century. These innovations have made a habit of drinking coffee simple, varied and enjoyable, and meet the needs of different consumer profiles. This is an exploratory research, which is a preliminary approach on the subject. The collected data show the strong presence of technological innovations throughout the modern history of coffee consumption. The first significant innovation was the sale of roasted coffee in standard paper bags. The paper bag was a novelty at the time. Until then, the most common was that the coffee was bought green and roasted at home. This innovation first began roasting and grinding industry in the U.S. Throughout the twentieth century, other innovations have contributed to the popularity of coffee consumption, such as soluble coffee, espresso machines, vacuum packaging and, more recently, single-cup machines. The analysis of these innovations showed that they were relevant in several aspects, including differentiation of coffee compared to other beverages. It concludes that the technological innovations have been of great importance to increase the consumption of coffee. They made the most versatile beverage consumption and differentiated, giving an advantage over the consumption of other beverages, whose differentiation is not so big. These results demonstrate that in the long run, innovation is critical to the coffee industry and should be encouraged. The sustained growth in demand for the product depends in part on the process of innovation. The results also highlight the importance of industry to the production chain, since the innovations promoted by it increased the demand for the product, with the consequent generation of jobs and opportunities in developed countries.

## **PU 604**

### **NEW TRENDS IN THE COFFEE INDUSTRY: THE THIRD WAVE COFFEE**

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In the last years, a new coffee consumer profile began to emerge. It is a discerning consumer, interested in knowing the origin of the purchased coffee, the particularities that differentiate a Brazilian coffee from a Colombian or Kenyan, for example. A consumer who wants to try different brewing methods that go beyond traditional espresso. This consumer lives called the "*Third Wave*" of coffee consumption. The expression "*Third Wave*" is quite recent, being used in some developed countries to identify a set of new trends of the specialty coffee consumption. In these countries, the major coffee shop chains that currently dominate the market are considered part of the Second Wave. For some consumers, drinking coffee can be even more sophisticated. The objective of this study was to approach, in a preliminary way, the phenomenon known as "*Third Wave*" of Coffee. From the principles of the Competitive Intelligence, we sought to better understand the characteristics of this new trend, so coffee producers of Minas Gerais state can adopt necessary measures to take advantage of the new emerging opportunities caused by the change in the preferences of "*Third Wave*" coffee consumers. Understand and anticipate changes in consumer demand is essential in modern economy, and agriculture is not an exception. The decisions of consumers has an impact on the entire production chain. Because it is something brand new, the data were collected over the internet. After that, were analyzed and grouped in order to better comprehend this phenomenon. Some of the "*Third Wave*" identified characteristics were:

- Increased interest by alternative coffee brewing methods, such as french press and, mostly, brewing.
- Larger interest of consumers know the specifics of each sensory origin.
- Valuing of micro lots of exclusive coffees over blends.

The results of this study point out that the Third wave is not fleeting. Although the number of adherents and establishments is still small, it must be remembered that gourmet and certified coffees market was once incipient, but today hold leading positions and great growth. The same can happen to the Third Wave. Finally, actions were suggested to contribute with coffee farmers of Minas Gerais state, so they can take better advantage of the new trends.

**PU 605**

**THE USE OF SOCIAL NETWORKS BY  
MAJOR COFFEE SHOP CHAINS**

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Social networks have great advantage over other forms of communication, as the exchange of information occurs in real time and allows the interaction between multiple users, wherever they are. Among them, the largest and most accessible in the world are Facebook, Twitter and LinkedIn, in order, according to data from March 2012, published in the Affiliate Networking website. The use of social networks is important for building relationships between company and client. It may exacerbate the effect of loyalty programs and approach the customer to the company, making him to feel important, respected and willing to recommend the brand to its known. As social networks are efficient in focusing communication on a very targeted and specific audience, as observed in coffee shop chains, these are examples of organizations that benefit significantly from their use. This study aimed to investigate the use of social networks by coffee shop chains e suggest actions for Brazilian players to publicize their brands in these media and attract more customers. For this, we analyzed three social networks most used by these organizations (Facebook, Twitter and YouTube) and the largest chains of coffee shops, fast food and restaurants (Starbucks, Costa Coffee, Café Coffee Day, Tim Hortons, McDonald's McCafé and Dunkin' Donuts). It was found that the optimal is to use these tools differently, aiming to manage the organization's image. Moreover, the main objectives of coffee shop chains in social networks are costumer relationship, strengthening the brand, promotion and dissemination of products or services, brand monitoring and e-commerce. From the study, it was also found that Starbucks is the coffee chain who better uses these tools, since it has the largest number of engaged clients in all three social networks analyzed. It was also found that Facebook is the most used social network by organizations in this market segment and also the most accessed by consumers, being the most appropriate for purposes of brand awareness and closeness to customers. Finally, the main strategy used in the relationship between company and customer have been posting official business photos and videos, touting new products and humanizing the consumer's vision of the company, offering an application for store locations, monitoring customers comments and providing information about the organization's loyalty card. It was concluded that the use of social networks can enhance the marketing activities of brazilian companies and, with more customer interaction with the brand, provide an increase in sales volume and consumer traffic in stores. As the investment required to use these tools is low, the cost/benefit relation of the strategy is positive to coffee shops. It is important noted that the increase in the number of brazilian who frequent coffee shops can bring gains to the economy. In addition to creating jobs in the sector, it rises the demand for specialty coffees, which is an opportunity to local coffee growers.

PU 606

## DO ROASTING CONDITIONS AFFECT CONSUMER LIKING FOR COFFEE BEVERAGES?

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Brazil is the first coffee producer and the second world market consumer of the beverage with potential for an increasing consumption in the near future. Coffee consumers are becoming more demanding in terms of beverage quality, and, as a consequence, the industry has to optimize coffee processing to deliver products that meet consumer expectations. Coffee roasting is a relevant step for the development of coffee flavor and aroma. It has a considerable effect on the beverage sensory characteristics, which will impact on consumer liking. Therefore, investigating consumer liking is a matter of recognized importance in the development and optimization of coffee beverages because it plays an important role when one chooses and buys such product. Considering that variation in taste attributes impact hedonic responses, it is important to investigate the consequences of different roasting conditions on consumer beverage liking. This study aimed at investigating the effect of roasting coffee conditions on consumer liking of beverages, taking into account individual preferences, in order to identify possible market niches. Brazilian good quality green Arabica coffee beans were roasted by varying the roasting temperature gradient in a semi-fluidized bed roaster (three speed conditions: slow, medium and fast), and the colour (moderately light and dark), yielding six different types of beans. Fifty-seven coffee drinkers (at least one cup of black coffee a day: 21 males and 36 females, aged between 18 – 65 years old) participated in the study. They evaluated the six beverages in terms of liking using 9-point structure hedonic scales, which varied from 1: disliked extremely to 9: liked extremely. Demographic and frequency of consumption data were also collected. Coffee brews at 10% (weight/volume) were prepared in electrical coffee makers using mineral water and monadically served to participants at  $68 \pm 2^\circ\text{C}$  in white porcelain cups coded with three digit numbers, following a balanced presentation order. They were evaluated in sensory booths under white light. Data were analyzed using ANOVA, Preference Mapping and Cluster Analysis. The first three dimensions of the PCA accounted for by 72.8% of the variance. The first dimension separated samples by roasting colour, and lighter coffee beverages were more liked by consumers, regardless of the speed conditions. Three segments of consumers were identified with different appreciation of samples. However, most of them (segments 2 and 3, 67% of participants) didn't like dark roasting in all speed conditions. The results demonstrated the importance of using consumers to identify adequate green coffee roasting conditions, and may provide valuable information to the industry.

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**PU 607**

## **STATE OF THE ART AND BACKGROUND OF COFFEE AGRIBUSINESS PUBLICATIONS IN AN IMPORTANT ECONOMY AND ADMINISTRATION BRAZILIAN CONGRESS IN THE LAST DECADE**

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The present study aimed to verify what has been studied on the coffee sector in the last ten years, in the range 2001 to 2011, in the Congress of the Brazilian Society of Economics, Administration and Rural Sociology (SOBER). The studies on bibliometrics and epistemological analysis of intellectual productions aim to collaborate with the character mappings of the academic society.

The SOBER is a relevant academic institution in Brazil that focuses on economics and rural sociology with over 50 years of existence. This work is direct result of the members of the Marketing and Consumer Behaviour Group (GECOM) at the Federal University of Lavras (UFLA) interest to map the production of foodstuffs in Brazil, when it was identified a gap in cluster and systematic studies of the Brazilian coffee sector.

Brazilian coffee business has great economic and social importance in several states and the national economy as a whole. Brazil is the world's largest producer, exporter and second largest consumer of coffee in the world in 2012, so the academic production of knowledge in various areas, from genetics to cup quality is also relevant in the context of national scientific production. It is important though to identify the path taken by coffee research in the coffee agribusiness in these areas, seeking to identify relationships with the context of global and Brazilian coffee agribusiness during the studied period.

We found 150 articles published in the Congress of SOBER in the period whose main subject was coffee. Of these, 59 articles proposed to discuss issues related to production in the coffee sector, 23 have opted for the study of the coffee industry and 62 articles focused on issues relating to the commercialization of the product. The content analysis revealed that the coffee researchers focused on aspects some major themes like productivity, exportation and product price strategies, what reflects the reality of Brazilian coffee agribusiness in the period studied.

In regards to production, we noticed a strong focus on issues related to yields and production systems, what shows on the one hand a productivist bias in the coffee business, perhaps a reflection of the very need of coffee growers in this period. However, one can notice researchers' concern on issues related to a more demanding consumer market that focus on quality and origin issues, as shown in the few studies in specialty and certified coffees.

On the subject exports, the articles reflect very well the dynamics of the sector in this period. Thus, it was realized the need for differentiation and adding value to raw materials and the strong dependence of the internal market to price swings in the international market. In addition, there are few studies on the dynamics of the internal market, and how it relates to exports. There is also lack of studies in niche markets.

Finally, analyzing, research in the pricing category revealed that the main factors that impact pricing strategies are associated with the organization of the market (internal and external) and the macroeconomic dynamics. This study helps coffee agribusinesses researchers, not only in Brazil, to advance in their studies on cutting-edge topics such as coffee marketing and certificates of origin, marketing strategies for different coffee qualities, coffee managerial aspects, family farming, among others.

## PU 608

## IN SEARCH FOR STRATEGIC CONVERGENCE IN BRAZILIAN COFFEE CLUSTERS

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Brazilian agribusiness has a recognized cooperative tradition. There are numerous examples of regional cooperatives which for years have provided and still provide services to Brazilian growers. The coffee, as part of our cultural and economic history, is no exception. There are important cooperatives working in micro and macro Brazilian coffee regions and have both economic and political relevance.

Another important instance of collective action by growers are the private interest associations. These are gaining an increasing importance in growers' interest articulation in recent years. Perhaps, its more flexible structure and focus on common goals that are not only related to financial issues are the main reasons for this category growth.

In coffee, due to its historical tradition linked to the emergence of many cooperatives, the phenomenon of associative structures through private interest associations is relatively recent. One explanation for the emergence of new associations is that growers needed other collective structures in order to represent their interests more specifically.

One of the main motivations for this profile change was the strengthening of the specialty coffee market in relation to coffee commodity produced in the country until then. Another important change was the appreciation of Brazilian micro and macro origins. As a result, the collective marketing strategies of specialty and origin coffee become an important competitive tool.

The analysis of the successful stories on this new era of the Brazilian coffee agribusiness allows for reflection: what these successful producers, their associations and cooperatives have in common? What strategies are used that lead to this success? In fact, the main reason for urban enterprises and agribusiness companies to seek association structures is the same, cooperate to better compete. Therefore, many theoretical approaches focus on the organizational forms that these associations have to seek to explain the mechanisms that ensure cooperation and competition. And it is from the 1980s that more systemic approaches appear to better comprehend these relationships, such as joint ventures, strategic alliances, supply chain management, clusters, and finally, the network approach.

The strategic convergence can be defined as the optimal point where much of the social actors inter-linked through a network in clusters have on common goals and are in convergence on the strategic direction that the network must follow.

The strategic convergence is related to networks and local clusters, and does not belong to a single company or sector. It involves social actors and recognizes that regardless of any plans and strategies, the most important thing is that the actors of this network are converging their thoughts to the same strategic objective. To perform the analysis of this research, we analyzed data from two distinct regions: the Cerrado region of Minas Gerais and Matas de Minas Gerais. We found data showing the strong strategic convergence in the Cerrado of Minas Gerais cluster. On the other hand, the lack of structural actions and focus on joint actions in the region of Matas de Minas Gerais resulted in lower strategic convergence.

## PU 609

APPROACH FOR COLOMBIAN COFFEE ORIGIN  
DENOMINATION PROJECT

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International markets are increasingly signaling demand for quality-differentiated coffee, which the Colombian Coffee Growers Federation (FNC) proposed to exploit to identify those regional coffees that would fulfill the requirements to be classified as denomination of origin

The objective of this study was to develop and implement a sound, robust and repeatable approach in order to identify regional causal relationships between coffee quality and environmental characteristics as bases for labels of denomination of origin.

Environmental differences between target coffee-growing areas in Colombia were statistically significant for several environmental elements including annual precipitation and diurnal temperature range, altitude, latitude, and soil characteristics either chemical or physical. Significant differences in biochemical compounds and sensorial product characteristics between the target regions. The spatial patterns in product characteristics exhibit a non-random, regionally-changing structure that is related to those in the environmental data.

The generated results provided ample evidence to support the application for regionally based denominations of origin for target coffee regions in Colombia.

## PU 610

## STUDENTS' PERCEPTION ABOUT COFFEE CONSUMPTION

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In order to attract new clients it is important to search for useful information and integrate it into companies' systems to achieve your audience. By understanding young consumers' relation with coffee, the companies will be able to create new ways to communicate and new projects to fulfill their needs.

The objective of this study was to evaluate what are the young students' perception on coffee in the municipality of Machado, state of Minas Gerais, Brazil, what is the average coffee consumption in this category and what is their opinion of coffee effects on health and concentration.

The research was conclusive, is descriptive in nature and quantitative. The method used personal interviews (Malhotra, 2001). The survey was conducted with students of the Instituto Federal Sul de Minas (IFSULDEMINAS), the Machadense Foundation of Higher Education and Communication (FUMESC) and the Center for Higher Education and Research (CESEP) in the city of Machado in the period between March and June 2008.

The ages of the students interviewed ranged from a minimum of 14 years and a maximum of 24 years. Of the total, the average age was 19.39 years, i.e. 19 years, 4 months and 20 days.

To perform the evaluation, the students had to fill out a questionnaire with multiple choice questions and with

space to comments if deemed necessary. During the filling out of the questionnaires it was recommended for participants to not interact with each other. One hundred and fifty students answered the questionnaire.

The type of sampling was non-probabilistic by quota on the proportion of the total number of students registered in IFSULDEMINAS and FUMESC. Because of the availability to interview students in CESEP, the number of students registered in the course of Agronomy was stratified.

The data were quantified and subsequently worked numerically and in percentage terms by employing multivariate statistical techniques. The individual questionnaires were tabulated and analyzed by the Statistical Package for the Social Science - SPSS and Microsoft Office Excel 2003.

Forty two respondents were female and one hundred eight were male. The results showed that 27.21% consume more than three (3) cups of coffee, while 23.13% reported to drink three cups of coffee, 18.37% drink two cups, 21.77% indicated that they consume only one cup, and 9.52% did not drink coffee.

Students that do not drink coffee said that they are not used to it, do not like or do not need. About the purchase decision, 59.3% said that they do not choose coffee in their homes, 34.7% choose by own preference (brand, tradition, etc.), 4.7% by sale and advertising, and 1.3% choose by the package. Data shows that students are completely unaware of coffee.

The question about whether they think that coffee is bad for health, 90.7% of the respondents answered no, 4.7% said yes and 4.7% were unable to reply. The highest percentage of answers saying that coffee is harmful was among non-consumers.

Students consider coffee as a beverage that helps on their concentration, within consumers the positive response was 65.4% against 34.6%. We can say that most the students interviewed has the habit of drinking coffee, but most do not interfere in the coffee purchase decision of their families.

**PU 611**

## CHARACTERIZATION OF BIOETHANOL OBTAINED FROM WASTE COFFEE INDUSTRY

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Currently worldwide there is a need to seek new alternative energy sources in order to reduce the economic and technological dependence on fossil fuels. In this research, most scientific studies have been focused on obtaining bioethanol from sugar-rich biological materials, which can be converted to ethanol by fermentation processes. The Coffee Growers Cooperative of Dota R.L, Coopedota R.L, has developed over the past five years a process for the obtaince of bioethanol from waste coffee pulp and mucilage present in the wastewater from production process. These wastewaters contain a high level of fermentable sugars which can be converted into bioethanol. In this context, through a collaborative project with SMEs, the National Laboratory of Metrology in Costa Rica, LACOMET, decides to generate an investigation which they purify and characterize the bioethanol produced Coopedota R.L, in order to establish whether this would comply with chemical and physical parameters to be used as biofuel. It is noteworthy that LACOMET has participated in recent years in international intercomparisons in measuring quality parameters of ethanol, having the expertise to analyze this type of material. The purification step of bioethanol initially consisted in removing suspended solids, organic material and high coloration containing in the crude bioethanol. Subsequently, the material was subjected to a distillation process in order to enrich the content of ethanol and remove possible contaminants. The material was characterized by establishing the content of ethanol, water content, acidity, density, color, UV-Vis and FTIR spectrum, suspended solids and ashes. The results show that the purified bioethanol has chemical and physical properties suitable for use and marketed as biofuel.

**PA 316****CALCINED KAOLIN (SURROUND WP) APPLICATION  
INFLUENCE ON STRESS REDUCTION AND COFFEE  
PRODUCTION IN COSTA RICA**

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The effect of calcined kaolin applications (Surround WP, Nova Source, USA) was assessed to control heat stress and increase production in coffee (*Coffea Arabica L.*) crop. Trials were carried out in coffee farms located in four different areas in Grecia (Los Ángeles and San Isidro) and Alajuela (Poás and San Isidro), Costa Rica, during the growing seasons of 2010-2011 (GS1) and 2011-2012 (GS2). A paired comparison statistical model «with and without» was used applying an «on farm research» approach for each individual experiment. Treatments of each location were the following: Los Angeles: T1) monthly applications of calcined kaolin (Surround WP) at 3% concentration of commercial product and T2) control without kaolin. Kaolin applications (Surround WP) were made after flowering (May, June, July, August, and September) of GS1 and GS2. San Isidro-Grecia and Poás: T1) monthly applications of calcined kaolin (Surround WP) at 2.5% and 5% concentration of commercial product during the GS1 and GS2, respectively and T2) control without kaolin. Kaolin applications (Surround WP) were made before flowering (March) and after flowering (May, June, July, August, and September) of GS1 and GS2. San Isidro- Alajuela: T1) applications of calcined kaolin (Surround WP) at 3% concentration of commercial product and T2) control without kaolin. Kaolin applications (Surround WP) were made before flowering (March) and after flowering (May, July, September, and November) of GS2. The following four variables were measured per hectare: number of “cajuelas”, volume, weight (kg) and number of harvested “fanegas”(estimated) during GS1 and GS2. Four replications (rows) of 45 experimental units (plants) each were used per treatment to evaluate yield. Coffee yield (“fanegas”) was higher for kaolin applications in all locations and years with the exception of San Isidro-Grecia in GS2 when the opposite occurred. In Los Angeles farm the number of “fanegas” was 11% and 60 % higher, respectively in GS1 and GS2 in comparison to the control treatment. San Isidro-Grecia farm showed 58% more number of “fanegas” in GS1 with calcined kaolin applications. Number of “fanegas” increased 7% and 19% in Póas farm in GS1 and GS2, respectively as compared to the control treatment and 39% in San Isidro-Alajuela farm in GS2. Calcined kaolin (Surround WP) has been tested in multiple research trials around the world. Its positive effect reducing sunburn damage and heat stress and increasing canopy light transmission, photosynthetically active radiation (PAR) and photosynthesis in many crops is widely recognized. These can be the reason of substantial productivity increases during two consecutive coffee harvests in Costa Rica.



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