Deciphering the genetic basis of adaptation to environment in *Theobroma cacao* using resequenced genomes

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Studying the genomic basis of adaptation of *Theobroma cacao*:

- To improve predictions of species’ adaptive capacities
- To provide accurate conservation strategies of genetic resources …

… in the context of increasing environmental pressures
Studying the genomic basis of adaptation

Altitudinal gradient mimics gradual climate change at a restricted geographic scale:
- temperature
- CO₂ partial pressure
- dryness
- UV radiation

102 accessions from collection expeditions sampled along an altitudinal gradient in Ecuador

Allen 1987, Loor et al 2015, Fouet et al 2022

➔ Joint analysis of genetic and environmental variations to identify functionally important genes contributing to the adaptive potential of the species
Climate data acquisition

WorldClim V 2.1 https://www.worldclim.org/

Database of high spatial resolution global weather and climate data used for mapping and spatial modeling

Fick et al 2017

➔ 22 climate variables:
11 linked with temperature, 8 precipitation + Solar radiation + Wind speed + Water vapor pressure
Climate data according to altitude

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**Genomic data**

**Whole genome shotgun sequencing** = Illumina paired-end 150 nt, Mean sequencing depth ≈ 50 X/accession

**Pan-genome reconstruction**

**Gene Presence-Absence Variation** (PAV)

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**Single Nucleotide Variation** (SNP)

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<td>SNP4</td>
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Genomic variation: PAV

28162 Core genes
2315 Variable genes

47 genes over-represented in the Cordillera population

87 genes over-represented in the Selva population

Fisher exact tests, qVal < 5%
Genomic variation : SNP

3 882 106 SNPs (without missing data)
Genomic signatures of selection

Genetic differentiation, $F_{ST}$
Selva vs. Cordillera

$\pi$ ratio
Cordillera / Selva

$\pi$ ratio
Selva / Cordillera
Genomic – Environment association

**LFMM (package LEA)**: GEA method accounting for population structure

\[ K=6, MAF > 5\% \]

- **Tc02cons_g033190**
- **Tc01cons_g034300**
- **Tc01cons_g036010**
- **Tc03cons_g014960**
- **Tc05cons_g006310**
- **Tc05cons_g006320**

**Altitude**

\[ \text{Chr1:34456620 Upstream transcript variant, gene Tc01const036010} \]

⇒ Identification of candidate genes linked to climate variables

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Conclusion

- Evidence of *genomic signatures of local adaptation* to altitude and climate in populations of cacao trees growing in highly contrasted environments
- Identification of candidate genes potentially involved in adaptation

**Perspectives:**

- Consider genetic adaptation to other important environmental variables: soil/pathogens
- Use genomic/climate association to assess the vulnerability of cacao production to future climate
Recommandations to farmers & to the ISCR community

- Farmers need **access to varieties adapted to the environmental conditions of their plantations**

- The whole community must **better characterize and preserve adaptive genetic diversity** to face future environmental changes

- We need to promote **ex-situ** (experimental stations) and **in-situ** (involving farmers, local communities...) **conservation initiatives**

⇒ cf poster Fouet et al S2.3
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Thank you for your attention

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