Recent advances in phylogenomics of some Neotropical woody plant families

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Frugivores & Seed Dispersal

St. Lucia, South Africa
June 21-25, 2015

http://www.fsd2015.ukzn.ac.za/
French Guiana

A long history and knowledge on engineering, tropical medicine, tropical forestry, and evolutionary ecology

Long-term funding (2011-2019)

Attractivity, excellence, transdisciplinarity
ceba: objectives

• Build a research environment on tropical ecosystems to promote research on biodiversity.

• Crystallize a vibrant network of researchers, all actively involved in biodiversity research in Amazonia (taxonomy, ecology, evolution, biogeochemistry, biomedical sciences, analytical chemistry, social sciences)

• Foster long-term research capacity building in France and in Europe, and strengthen relationships with South American partners.

Science plan

AMAZOMICS
23 people

biodiscovery

DIADEMA
57 people

genetics & ecology of adaptation

biodiversity & ecosystem processes of biodiversity

PHYLOGUINANAS
31 people

modelling biodiversity in space & time

BIOHOPSYS
31 people

FUN-CHEM
41 people

services of biodiversity

ABIOS
21 people
Annual calls for proposals (next deadline 23 Jan 2015)

Open to all teams outside of the lab
please apply

Hyperdominance in the Amazonian Tree Flora

Hans ter Steege, 1,2+a Nigel C. A. Pitman, 3,4 Daniel Sabatier, 5 Christopher Baraloto, 6 Rafael P. Salomão, 7 Juan Ernesto Guevara, 8 Oliver L. Phillips, 9 Carolina V. Castilho, 10 William E. Magnusson, 11 Jean-François Molino, 5 Abel Monteagudo, 12 Percy Núñez Vargas, 11 Juan Carlos Montero, 14,11 Ted R. Feldpausch, 9,15 Eurídice N. Honorio Coronado, 16,9 Tim J. Killeen, 17 Bonifacio Mostacero, 18 Rodolfo Vasquez, 12 Rafael L. Assis, 13,19 John Terborgh, 3 Florian Wittmann, 20 Ana Andrade, 21 William F. Laurance, 22 Susan G. W. Laurance, 22

We compiled stem density and species abundance data from 1170 tree inventory plots across the Amazon (Fig. 1), well distributed among all regions and major forest types (table S1 and figs. S1 to S3), to generate basin-wide estimates of the abundance, frequency, and spatial distribution of thousands of Amazonian tree species.

Results

A Rank-Abundance Distribution for Amazonian Trees

The plots contained a total of 4962 valid species, 810 genera, and 131 families of trees [free-
Tectonic-driven climate change and the diversification of angiosperms

Anne-Claire Chaboceau\textsuperscript{a,1}, Pierre Sepulchre\textsuperscript{a}, Yannick Donnadieu\textsuperscript{a}, and Alain Franc\textsuperscript{b}

\textsuperscript{a}Laboratoire des Sciences du Climat et de l’Environnement, Unité Mixte, Centre National de la Recherche Scientifique–Commissariat à l’Energie Atomique–Université de Versailles Saint-Quentin-en-Yvelines, 91191 Gif-sur-Yvette, France; and \textsuperscript{b}Unité Mixte de Recherche Biodiversité, Gènes et Communautés, Institut National de la Recherche Agronomique, 33612 Cestas, France

Edited by Robert E. Dickinson, The University of Texas at Austin, Austin, TX, and approved August 1, 2014 (received for review December 23, 2013)

In 1879, Charles Darwin characterized the sudden and unexplained rise of angiosperms during the Cretaceous as an "abominable mystery." The diversification of this clade marked the beginning of covers the large uncertainties of pCO\textsubscript{2} estimates for these geological periods.

To validate our paloclimatic experiments, the geographical

D  Cenomanian - 95 Ma (best fit model-data)
Species delimitation, patterns of diversification and historical biogeography of the Neotropical frog genus *Adenomera* (Anura, Leptodactylidae)

Antoine Fouquet¹,²*, Carla Santana Cassini³, Célio Fernando Baptista Haddad³, Nicolas Pech⁴ and Miguel Trefaut Rodrigues²

**Results** Our conservative delineation identified 31 Confirmed Candidate Species (four remaining unconfirmed) representing a 94% increase in species richness. The biogeographical analysis suggested an Amazonian origin *Adenomera* with as many as three dispersals to the DD and one to the AF during the Miocene. These dispersals were associated with habitat shifts from forest towards open habitats.
Health programs

Active projects on the epidemiological monitoring, ecosystemic context, and chemical resistance on

- Malaria
- Leishmaniosis
- Chagas disease
- Buruli ulcer
- Toxoplasmosis
- Histoplasmosis
Chemistry of natural products

Genetic signature

Microorganisms

Secondary metabolites for:
- Defense
- Communication

Plants

Insects

Humans

Metabolomic signature

Bio-inspired biological activities

Bioactive functional metabolites

D Stien, Oct 2014
Coping with biodiversity in evolving legal and political frameworks

Access and Benefit Sharing

• Access needs to be consensual, realistic, flexible to be applicable and fruitful for both parties

• Companies & academic researchers who invest in research must get legal security

• Without research investment, no benefice and therefore no benefit sharing

• Access should be facilitated for the fair, equitable benefit of all (providers, industries, patients) and biodiversity preservation
Canopy Permanent Access System (COPAS)

New eddy-flux tower (Nouraflux) October 2014
Recent advances in phylogenomics of some Neotropical woody plant families
Why are the tropics so diverse?
Tropics as a cradle for diversification

More UV irradiance $\Rightarrow$ higher mutation rate $\Rightarrow$ higher diversification rates

Armen Takhtajan (1910-2009)
Tropics as a museum for diversity

Tropical Nature (1878)

Alfred Russel Wallace
1823-1913
Phylogenies provide a crucial information on the tempo of diversification

Only extant taxa are usually sampled

Branch length corresponds to the most recent common ancestor in a lineage

Rate of change calibrated using the fossil record
Support for the museum hypothesis

Cenozoic Plant Diversity in the Neotropics

Carlos Jaramillo, Milton J. Rueda, Germán Mora

www.sciencemag.org  SCIENCE  VOL 311  31 MARCH 2006
Support for the cradle hypothesis

Rapid Diversification of a Species-Rich Genus of Neotropical Rain Forest Trees
The story of *Cyathostegia*.

*Pennington et al. PNAS 2010*
Support for the cradle hypothesis
A necessarily complex model:
role of intracontinental vicariance and orogeny

AH Gentry, Ann Miss Bot Garden, 1982
Questions

1. Have predominantly Neotropical plant families originated in situ?

2. Has the tempo of diversification been steady in Neotropical plant families?

3. Can major diversification events be related to environmental change events?
**Most abundant tree families in Amazonia**

<table>
<thead>
<tr>
<th>Family</th>
<th>%abundance</th>
<th>rank</th>
<th>%species</th>
<th>rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabaceae</td>
<td>15.3</td>
<td>1</td>
<td>16.0</td>
<td>1</td>
</tr>
<tr>
<td>Sapotaceae</td>
<td>6.1</td>
<td>4</td>
<td>4.2</td>
<td>5</td>
</tr>
<tr>
<td>Malvaceae</td>
<td>4.9</td>
<td>5</td>
<td>3.4</td>
<td>8</td>
</tr>
<tr>
<td>Annonaceae</td>
<td>3.4</td>
<td>11</td>
<td>5.8</td>
<td>3</td>
</tr>
<tr>
<td>Chrysobalanaceae</td>
<td>4.5</td>
<td>8</td>
<td>3.9</td>
<td>6</td>
</tr>
<tr>
<td>Lauraceae</td>
<td>2.7</td>
<td>12</td>
<td>6.2</td>
<td>2</td>
</tr>
<tr>
<td>Lecythidaceae</td>
<td>7.9</td>
<td>3</td>
<td>2.1</td>
<td>14</td>
</tr>
<tr>
<td>Moraceae</td>
<td>4.8</td>
<td>6</td>
<td>2.7</td>
<td>11</td>
</tr>
<tr>
<td>Euphorbiaceae</td>
<td>4.4</td>
<td>9</td>
<td>2.9</td>
<td>10</td>
</tr>
<tr>
<td>Arecaceae</td>
<td>9.4</td>
<td>2</td>
<td>1.4</td>
<td>19</td>
</tr>
</tbody>
</table>

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Chrysobalanaceae

- Mid-sized family with ca 500 species, 80% of them in the Neotropics

- Taxonomy of the family has been carefully researched since the 1960s
18/73 nodes supported (PP > 80%) 24% of the nodes

Basal nodes poorly resolved
Sapotaceae: Chrysophylloideae

- Ca 1200 species; ca 600 species in subfamily Chrysophylloideae

- Remarkably species-rich in the French Guiana tree flora

- Little support for phylogenetic relations at the base of tree
Humiriaceae

Ca 60 species

Excellent fossil record (by Neotropical plant families standards), recently revised

Only Neotropical (except 1 species, African)
Using plastid genome-scale data to resolve enigmatic relationships among basal angiosperms

Michael J. Moore*, Charles D. Bell*, Pamela S. Soltis†, and Douglas E. Soltis‡

†Department of Botany and §Florida Museum of Natural History, University of Florida, Gainesville, FL 32611; and ‡Department of Biological Sciences, University of New Orleans, New Orleans, LA 70149

Communicated by David L. Dilcher, University of Florida, Gainesville, FL, August 28, 2007 (received for review June 15, 2007)

Although great progress has been made in clarifying deep-level angiosperm relationships, several early nodes in the angiosperm branch of the Tree of Life have proved difficult to resolve. Perhaps as sister to magnoliids, Ceratophyllum, or as part of a clade with magnoliids and Chloranthaceae, generally with low support (7, 12, 15, 17, 19–24). The unstable relationships exhibited among

BMC Biology

BMC Biology 2009, 7:84

Research article

Increasing phylogenetic resolution at low taxonomic levels using massively parallel sequencing of chloroplast genomes

Matthew Parks¹, Richard Cronn² and Aaron Liston*¹

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* Corresponding author

ASSEMBLING THE TREE OF THE MONOCOTYLEDONS: PLASTOME SEQUENCE PHYLOGENY AND EVOLUTION OF POALES¹

Thomas J. Givnish,‡ Mercedes Ames,‡ Joel R. McNeel,§ Michael R. McKain,§ P. Roxanne Steele,‡ Claude W. dePamphilis,§ Sean W. Graham,§ J. Chris Pires,§ Dennis W. Stevenson,§ Wendy B. Zomlefer,§ Barbara G. Briggs,§ Melvin R. Duvall,§ Michael J. Moore,† Michael Heaney,† Douglas E. Soltis,¹ Pamela S. Soltis,¹ Kevin Thiele,¹ and James H. Leebens-Mack²

Shotgun sequencing

Shearing

Illumina seq

No plastid DNA enrichment
Assembling sequencing reads

Eric Coissac
Grenoble, France
Results

1. Chrysobalanaceae
Chrysobalanus icaco
chloroplast genome
162,775 bp

Genome skimming by shotgun sequencing helps resolve the phylogeny of a pantropical tree family

PIERRE-JEAN G. MALÉ,* LÉA BARDON,* GUILLAUME BESNARD,* ERIC COISSAC,† FRÉDÉRIC DELSUC,§ JULIEN ENGEL,¶ EMELINE LHUIILLIER,** CAROLINE SCOTTI-SAINTAGNE,¶ ALEXANDRA TINAUT† and JÉRÔME CHAVE*
Chrysobalanaceae ptDNA phylogeny

50 fully assembled plastid DNA genomes (all of them new)

Tree with 100% node support

Outgroup: *Euphronia guianensis* (collaboration with CD Davis & Z Xi, Harvard)

For questions, collaborations, please contact lea.bardon@gmail.com

Bardon et al. unpublished
For questions, collaborations, please contact lea.bardon@gmail.com
Chrysobalanaceae ptDNA phylogeny

For questions, collaborations, please contact lea.bardon@gmail.com

Bardon et al. unpublished
Take-home messages

1. **Couepia** is split into two genera (type ‘parillo’ becomes *Gaulettia* Sothers et al. 2014)

2. **Licania** is split into four genera (*Licania ss*, ‘*heteromorpha*’ clade, ‘*minutiflora*’ clade, *Licania michauxii*)

3. Ancestral lineage is *Kostermanthus*, followed by *Parinari* ➔ the family originated in the paleotropics in spite of its dominance in the Neotropics

4. The fossil record in this family is too sparse to draw firm conclusions about its tempo of diversification
Results

2. Sapotaceae
31 full plastid DNA genomes (unpublished)

Three partitions on cpDNA

Total length 130,000 bp

12 clades at the base of the Neotropical clade, with no support

Chave et al. unpublished
Take-home messages

• Diversification in Sapotaceae: Chrysophylloideae is associated with a sudden burst, possibly linked to the K/T transition (65 Ma ago)

• Polyphyly in both Chrysophyllum and Pouteria is obvious, but more sampling is needed to better explore this (work in progress)
Results

3. Humiriaceae
Humiriaceae ptDNA phylogeny

For questions, collaborations, please contact lea.bardon@gmail.com
Diversification patterns

For questions, collaborations, please contact lea.bardon@gmail.com
Humiriaceae: molecular vs morphology

Bardon et al. unpublished

Main findings

1. Have predominantly Neotropical plant families originated in situ?
   ➔ No, Chrysobalanaceae are a clear-cut case of paleotropical origination with secondary dispersal into the Neotropics

2. Has the tempo of diversification been steady in Neotropical plant families?
   ➔ Not always, Sapotaceae:Chrysophylloideae show a surprising pattern of explosive diversification that may have coincided with the Cretaceous-Paelogene transition

3. Can major diversification events be related to environmental change events?
   ➔ Yes, in Humiriaceae stages of diversification seem to coincide with period of flooding of the Pebas system
Discussion

‘the fact that the entire plastid tracks a single phylogeny is a liability in cases of introgression ("plastid capture") and incomplete lineage sorting (aka "deep coalescence").

It is not known to what degree plastid-based studies at the genus or family level may produce precise gene trees that are inaccurate as species trees. This is not a new concern (e.g., Doyle, 1992).'}
Perspectives

• Completing the sampling in various regions: we’d love to collaborate with anyone interested

• Funded sequencing of several hundred Amazonian plant species in 2015

• Implementing this approach on other groups in the Guiana Shield (amphibians, opilions): strategic CEBA project
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