From Genome to Gene: Exploring the Cacao Genome to Discover Disease Resistance Mechanisms

2nd World Cocoa Summit
August 27th, 2014
Guayaquil, Ecuador

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Outlin

• Introduction
• Production Statistics
• Threats to Production
• Role of Science
• The Cacao Genome
• The Cacao Immune System

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Global Cocoa Production

World total 3,635,000 Tons/Year (2009-2010)
$9.1 billion dollars at commodity prices

Source: ICCO Quarterly Bulletin of Cocoa Statistics
Global Cocoa Plantings are Increasing

Plantaciones en el mundo están creciendo

$R^2 = 0.9867$

World + (Total) Area harvested (Ha)

Polinómica (World + (Total) Area harvested (Ha))

New plantings at about 250,000 ha/year

But how long can this be sustainable?

Global Cocoa Yields/Ha are Flat

But will this increase or decrease?

Source FAOSTAT [http://faostat.fao.org]
Global Supply Has Been Keeping Pace with Increase in Demand at the Same Rate

Global Cocoa Production and Use

What will the future demand be?

Cual sera la demanda futura?

Source: International Cocoa Organization
http://www.icco.org/

Predictions: M. Guiltinan unpublished

March 2014
If production cannot keep pace, and demand is high… What will be the new reality?

If la producción no se mantiene y la demanda es grande… ¿Cuál será la nueva realidad?

Global Cocoa Production and Use

Predictions: M. Guiltinan unpublished

Crisis or Sustainability?
Threat or Opportunity?

This Depends on Your Point of View
The Future of the World's Chocolate is in Our Hands!
Sustainability of the Cocoa Value Chain

Reality Check

• Demand WILL increase! (but could slow if prices go too high)

• We must plant more and/or increase yield/ha

• Increase in planting area is not sustainable

• Yields per ha must increase!
  • High yielding varieties
  • Better disease control
  • Better agricultural practices

• But, we must be sure not to……!
Reasons for Low Productivity

- Reduced use of fungicides and fertilizers
- *Soil Depletion*
- Ageing trees (55% over 20 years old, past peak productivity)
- Poor Genetics (~60% of all trees unselected, low genetic potential)
- Climate change
  - El Nino related climate change = 2.4% global reduction during past decade
  - Severe harmattan conditions in W. Africa
- Farm abandonment
  - Poor yields = low incomes
  - Few young people to take over farms from ageing farmers
- Political change and strife
Focus on Cacao Diseases

- What and where are the main cacao diseases?
- Breeding for resistance to cacao diseases is slow, can we accelerate this?
- Understanding the genetics of cacao disease resistance will help breeders to move faster and more efficiently.
  - What are the genes for resistance?
  - What varieties have the best resistance genes?
  - What are the best strategies to guide plant breeding programs?
Three Key Biotic Threats to Cacao Production

- **Black Pod Rot**: Phylophthora capsici, P. citrophthora, P. megakarya, & P. palmivora
- **Ubiquitous**
- **Witches’ Broom**: Moniliphthora perniciosa
- **South and Central America**
- **Frosty Pod**: Moniliophthora roreri
- **South and Central America**

Estimated 40% of potential cocoa yields are lost to pests and diseases each year.
Movement of Monilia

Moniliasis en Mesoamerica

W. Phillips, CATIE, Costa Rica


Movement of Witches Broom

Distribution of witches’ broom

W. Phillips, CATIE, Costa Rica
Spread of Cocoa Swollen Shoot Virus in West Africa

Details and extend of current distribution largely unknown.
THE BIGGEST Threat!

Long distance spread

- Cereals stem rust
- Wheat yellow rust
- Sugarcane rust
- Coffee leaf rust
- Wheat stem rust
- Chestnut blight
- Potato late blight

Direct movement of airborne spores
Periodic migrations
Infected plant material (people)


R.Sgrillo – CEPLAC/MAPA-2010
The use of advance cacao science to develop the future of cacao value chain

Cacao Plants of the Future
Cacao Farms of the Future
Cacao Value Chain of the Future
Genome Sequence
- Basic Knowledge
- Gene Discovery
- Trait Discovery
- Allele Mining
- Molecular Markers

How Will Chocolomics Lead to Helping Farmers and a Sustainable Cocoa Supply?

Accelerated Breeding

Increased Farm Productivity and Income

Sustainable Cocoa Supply
The genome of *Theobroma cacao*


*Nature Genetics* (2010) doi:10.1038/ng.736
Received 10 August 2010 Accepted 01 December 2010 Published online 26 December 2010
Why Sequence the Cacao Genome?

Porque secuenciar el genoma?

Future Impacts of Cacao Genomics

Through accelerated breeding will come:

- Increased Farm Productivity
- Enhanced Farmer Livelihoods (5-6 million farmers and their families)
- Support a Sustainable Chocolate Industry
- Environmental, Social and Economic Benefits
Why Sequence the Cacao Genome? 
Porque secuenciar el genoma?

- Applied Science Goals
  - Acceleration of Plant Breeding Programs
  - Management of Cacao Genetic Diversity

- Basic Science Goals
  - Explore The Evolution and Genetic Diversity of Cacao
  - Understanding the Growth and Development of Cacao
  - Explore Disease Resistance Mechanisms
  - Explore the Genetic Basis of Key Metabolic Pathways
The International Cocoa Genome Sequencing Consortium
61 Scientists from 23 Institutions
The Genome of Theobroma cacao

What is a Genome?

• All DNA in an organism.
• Contains all the genes needed to construct and maintain a living organism.
• Long stretches of the four basic building blocks A, C, G, and T (nucleotide bases).
• 430,000,000 bases/10 chromosomes
• The genome sequence is the determination of the order of all bases of each chromosome.
• Allows identification of all of the genes.
The Genome of *Theobroma cacao*

- 10 chromosomes
- Diploid
- \(2n=20\)

*In situ* hybridization of *T. cacao* chromosomes stained with DAPI (blue) using a *ThCen* repeat probe (red).