Banana breeding program at Embrapa Cassava & Fruits

Edson Perito Amorim
Banana production in Brazil

(1000 x ha)

Million tons

India 7.6
Philippines 6.3
Brazil 27.0
China 9.0
Ecuador 9.0
Indonesia 6.3
Tanzania 3.2
Guatemala 2.5
Costa Rica 2.4
Economic importance

- It is the second most consumed fruit in Brazil and as key complementary food for the low-income population;
- Domestic consumption: 98% of production;
- Exports: ± 2% (Argentina…)
- Number of farmers: 63,000;
- Direct jobs: ± 500,000;
- Indirect jobs: ± 1.5 million
Main problems

• Pests and diseases:
  ✓ Black and Yellow Sigatoka
  ✓ Panama disease (Silk, Prata and Cavendish)
  ✓ BSV (AAB type)
  ✓ Nematodes, Cosmopolites sordidus...

• Plant height: usually high

• Post-harvest losses: 30%

• Fruit quality: low shelf life (Prata type)
Main problems

- Panama disease in Cavendish: increased frequency in Brazil

Bahia State

Santa Catarina State

Rio Grande do Sul State

São Paulo State
Main problems

- Black Sigatoka: dispersion in Brazil

![Map showing the dispersion of disease in Brazil from 1998 to 2004.](image)
Main cultivars

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Subgroup</th>
<th>Genomic group</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prata</td>
<td>Prata</td>
<td>AAB</td>
<td>PH H, YS S, BS S, PD S</td>
</tr>
<tr>
<td>Pacovan</td>
<td>Prata</td>
<td>AAB</td>
<td>PH H, YS S, BS S, PD S</td>
</tr>
<tr>
<td>Prata-Anã</td>
<td>-</td>
<td>AAB</td>
<td>PH ML, YS S, BS S, PD S</td>
</tr>
<tr>
<td>Maçã</td>
<td>-</td>
<td>AAB</td>
<td>PH MH, YS MS, BS S, PD HS</td>
</tr>
<tr>
<td>Mysore</td>
<td>-</td>
<td>AAB</td>
<td>PH ML, YS R, BS R, PD R</td>
</tr>
<tr>
<td>D`Angola</td>
<td>Plantain</td>
<td>AAB</td>
<td>PH M, YS R, BS S, PD R</td>
</tr>
<tr>
<td>Terra</td>
<td>Plantain</td>
<td>AAB</td>
<td>PH H, YS R, BS S, PD R</td>
</tr>
<tr>
<td>Nanicão</td>
<td>Cavendish</td>
<td>AAA</td>
<td>PH ML, YS S, BS S, PD R ??</td>
</tr>
</tbody>
</table>

PH: plant height (H: high, ML: medium-low, MH: medium-high, M: medium); YS: Yellow Sigatoka (S: susceptible, MS: moderately susceptible, R: resistant); BS: Black Sigatoka (S: susceptible, R: resistant); PD: Panama disease (S: susceptible, HS: high susceptible, R: resistant)
Cultivars

- Prata Subgroup

Prata Comum

Pacovan

Prata Anã
Cultivars

Maçã

Preferred by consumers, however, is highly susceptible to Panama disease
The fruits are consumed in the Southeast of Brazil and exported to Argentina and other South American countries.
Cultivars

- Plantains

D’Angola (Horn)  Terra Maranhão (French)

Important in the Northeast and Northern of Brazil
Susceptible to black Sigatoka
Banana breeding - Embrapa

• A brief history:

✓ Began in November 1976;

✓ Hybridization between wild diploids and triploids - development of Prata-type tetraploid hybrids;

✓ From 1993 - development of tetraploid hybrids similar to the Maçã cultivar (Silk);

✓ Today - development of triploid and tetraploid hybrids (hybrids between ID and tri- and tetraploids).
Banana breeding – Main objectives

- Fruit quality: taste and flavor similar to Prata and Maçã/Silk
- Plant height: low height (develop ID)
- Early flowering
- Strong root system
- Nematode resistance (*Radopholus similis*)
Banana breeding – Main objectives

✔ Salinity resistance

✔ Drought tolerance

✔ Diseases resistance: YS, BS and **PD (most important)**;

✔ New **plantain cultivars**: BS resistance (PD and YS are important)

✔ Biofortification: new hybrids (high quantity of carotenoids)
Banana breeding - Embrapa

- Infrastructure and human resources:
  - 07 hectares of experimental fields;
  - 01 Cultural practices laboratory;
  - 03 Greenhouses;
  - 03 Nurseries;
  - 07 Embrapa employees and 05 temporary employees;
  - 21 Researchers (areas): breeding, biotechnology, plant pathology, soil and plant nutrition, post-harvest technology, food technology, economy, and others.
## Banana breeding - Embrapa

### Germplasm collection: description

<table>
<thead>
<tr>
<th>Maintenance Condition</th>
<th>Total Nº of accessions</th>
<th>Wild sp.</th>
<th>Cultivated Breeding lines</th>
<th>Other types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>412</td>
<td>52</td>
<td>315</td>
<td>43</td>
</tr>
<tr>
<td>In vitro</td>
<td>412</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criopreservation</td>
<td>50 (new strategy, beginning in 2012)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sections: Eumusa, Rhodochlamys and Callimusa
Banana breeding - Embrapa

- Accessions: were collected in different places
Banana breeding - Embrapa

- Germplasm collection: was evaluated for...

- Drought tolerance
- Salinity
- CMV
- BSV
- Nematodes
- Moko
- Panama disease
- Black Sigatoka
- Yellow Sigatoka
- DArT
- SSR
- RFLP
- RAPD
- Ornamental
- Functional compounds
- Ploidy
- Morphoagronomic
- Yellow Sigatoka
- Black Sigatoka
- Panama disease
- Moko
- Nematodes
- Salinity
- Drought tolerance
Description of breeding methods

**First Strategy**

- AA
- AA
- 43 ID AA
- AAB

**Second Strategy**

- AAAB/AAAA
- ID AA
- Hybrids AAB or AAA
  - Secundary Triploids
- Hybrids AAAB

Photos: internet
Description of breeding methods

Diploid hybrids

- 1850 new hybrids in evaluation (2013);
- YS, BS, PD and agronomic characteristics in evaluation (2013).
Description of breeding methods

Tri- and tetraploids hybrids

- 135 hybrids triploids, and 600 tetraploids in evaluation - 2013 (crosses between commercial tri- and tetraploids cultivars developed by Embrapa and improved diploids).
Breeding strategies - Embrapa

Third strategy: Double chromosomes

- AA
- AA or BB
- ID AA or AB
- Treatment with colchicine
- AA or AABB
- AAAAA or AABBB
- ID AA or BB
- Field evaluation (±100 hybrids)
- Hybrids AAB or AAA Secondary Triploids

Photos: Embrapa
Breeding strategies - Embrapa

Fourth strategy: evolutionary breeding

Purpose: Identification of banana diploid ancestors

✓ Crosses with commercial Tri- and Tetraploids
✓ Double chromossomes

de Jesus et al. BMC Plant Biology 2013, 13:41
http://www.biomedcentral.com/1471-2229/13/41

Genetic diversity and population structure of Musa accessions in ex situ conservation
Breeding strategies - Embrapa

- Cross scheme: held ever day
Breeding strategies - Embrapa

- Development and evaluation of new hybrids

Crosses (AA x AA; AA x Triploids; AA x Tetraploids)

Phase one (3 years)

Selection

Seeds

Clonal phase (2 years)

Selection → Panama disease evaluation (2 years)
Panama disease evaluation - field

New hybrid

Silk/Maçã
Panama disease evaluation - field
Panama disease evaluation - field
Panama disease evaluation – greenhouse

Susceptible

Moderately resistant

Resistant
Breeding strategies - Embrapa

- Development and evaluation of new hybrids

Selection → Black Sigatoka evaluation (2 years)
Selection → Field evaluation (3 years)

Total: 12 years → New cultivar release

Molecular biology tools → 7-8 years
Breeding strategies - Embrapa

• Field and commercial evaluation: 30 locations in Brazil

Today: 23 promising genotypes under evaluation

Possibility of evaluation in other Countries (13 cultivars)
Cultivars - Embrapa

Pacovan (AAB)

- Prata type;
- Mutation (Prata Comum);
- Plant height: high;
- Bunch weight: 16 kg;
- Production: 40 t ha\(^{-1}\);
- **Recommended by Embrapa (1985).**

Disease

YS: susceptible
BS: susceptible
PD: moderately susceptible
**Cultivars - Embrapa**

**Prata Anã (AAB)**

- Prata type;
- Plant height: dwarf;
- Production: 35 t ha$^{-1}$;
- Recommended by Embrapa (1985);
- Around 60% area in Brazil.

**Disease**

YS: susceptible
BS: susceptible
PD: susceptible
Hybrids - Embrapa

BRS Caprichosa (AAAB)

✓ Prata type;
✓ Hybrid: Prata Comum x ID;
✓ Plant height: high;
✓ Large fruit (± 18 cm);
✓ Production: 40 t ha\(^{-1}\).

**Disease**

YS: Resistant
BS: Resistant (northern of Brazil)
PD: Resistant
BRS Garantida (AAAB)

- Prata type;
- Hybrid: Prata São Tomé x ID;
- Plant height: high;
- Short cycle (± 200 days);
- Production: 30 t ha$^{-1}$.

**Disease**
- YS: Resistant
- BS: Resistant (northern of Brazil)
- PD: Resistant
Prata type;
Hybrid: Pacovan x ID;
Plant height: high;
Medium cycle (± 400 days);
Production: 30 t ha\(^{-1}\).

**Disease**

YS: Resistant
BS: Resistant (northern of Brazil)
PD: Resistant
Hybrids - Embrapa

BRS Pacovan Ken (AAAB)

- Prata type;
- Hybrid: Pacovan x ID;
- Plant height: medium-high;
- Medium cycle (± 450 days);
- Production: 30 t ha\(^{-1}\).

Disease

YS: Resistant
BS: Resistant
PD: Resistant
BRS Preciosa (AAAB)

- Prata type;
- Hybrid: Pacovan x ID;
- Plant height: high;
- Production: 40 t ha$^{-1}$.

**Disease**

YS: Resistant
BS: Resistant
PD: Resistant

Photo: Edson Perito Amorim
Hybrids - Embrapa

BRS Vitória (AAAB)

✓ Prata type;
✓ Hybrid: Pacovan x ID;
✓ Short cycle;
✓ Shelf life: long;
✓ Production: 40 t ha⁻¹.

**Disease**

YS: Resistant
BS: Resistant
PD: Resistant
Cultivars - Embrapa

Maça (AAB)

- Silk type
- Plant height: medium-high;
- Sweet taste;
- Market price: high;
- Bunch weight: 15 kg;
- 07-10 hands;

Disease

YS: Moderately resistant
BS: Susceptible
PD: High susceptible

Photo: Edson Perito Amorim
Hybrids - Embrapa

BRS Tropical (AAAB)

- Silk type;
- Hybrid: Yangambi n°2 x ID;
- Similar to Maçã (AAB);
- Production: 20 t ha\(^{-1}\)

Disease

YS: Resistant
BS: Susceptible
PD: Tolerant
Hybrids - Embrapa

BRS Princesa (AAAB)

- Silk type;
- Hybrid: Yangambi n°2 x ID;
- Similar to Maçã (AAB);
- Production: 25 t ha\(^{-1}\)

Disease

YS: Resistant
BS: Susceptible
PD: high tolerant

Photo: Edson Perito Amorim
Cultivars - Embrapa

Thap Maeo

- Origin: Thailand;
- Plant height: medium-high;
- Production: 25 t ha\(^{-1}\);
- Rusticity;
- 15 hands;

Disease

YS: Resistant
BS: Resistant
PD: Resistant
Hybrids - Embrapa

BRS Conquista

- Silk type;
- Mutant (Thap Maeo);
- Similar to Maçã (AAB);
- Production: 25 t ha⁻¹

Disease

YS: Resistant
BS: Resistant
PD: Resistant

Photos: Edson Perito Amorim
Cultivars – Embrapa

Caipira (AAA)

- Plant height: medium-high;
- Origin: Africa;
- 07-09 hands;
- ≅ Maçã;
- Production: 30 t ha\(^{-1}\).

**Disease**

YS: Resistant
BS: Resistant
PD: Resistant
Cultivars - Embrapa

Ouro

- Plant height: medium-high;
- 10-12 hands;
- Small fruits;
- ≈ Maçã;
- Diploid AA

Disease

YS: Susceptible
BS: Moderately resistant
PD: Resistant
Hybrids - Embrapa

BRS Platina (AAAB)

☑ Prata type;
☑ Hybrid: Prata Anã x ID;
☑ Similar to Prata Anã (AAB);
☑ Production: 45 t ha⁻¹

Disease

YS: Resistant
BS: Moderately resistant
PD: Resistant
Hybrids - Embrapa

BRS Platina (AAAB)
Non-conventional breeding - Embrapa

- MAS (TR4, Sigatokas, Foc race 1);
- Phylogeny;
- Fingerprinting (hybrids and improved diploids);
- Plant x pathogen interactions (genes discovery);
- Diversity and population structure
- Proteomics: drought tolerance and pos-harvest quality;
- Transgenic/Cisgenic.
Non-conventional breeding - Embrapa

MAS (TR4): SCAR marker

- Resistant
- Resistant
Non-conventional breeding - Embrapa

Phylogeny
Non-conventional breeding - Embrapa

Plant x pathogen interactions: Foc

“Silk: susceptible”

“BRS Platina: resistant”
Non-conventional breeding - Embrapa

Plant x pathogen interactions: *M. musicola*

**Ilumina HiSeq2000**

- The differentially expressed genes have been identified for the main interactions (Grande Naine, Caipira, 5, 10, 15 and 20 and 30 d.a.i., and controls);
- Identification of EST-SSRs and primer design are underway as well as validation studies;
- SNPs, candidate genes.
Non-conventional breeding - Embrapa

Diversity and population structure (*M. Musicola*) and virulence and aggressiveness tests

**ISSR**

**ITS**

**SSR**
Non-conventional breeding - Embrapa

Diversity and population structure \((Foc)\) and virulence and aggressiveness tests
Non-conventional breeding - Embrapa

Proteomics: drought tolerance

Identification of contrasting banana varieties as to drought tolerance: Prata Anã (susceptible) and Tropical (tolerant)

Differentially expressed proteins

Mass spectrometer – Q - TOF
GRACIAS
THANK YOU!
OBRIGADO

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