Early Generation Seed Case Studies
Brazil Banana

June 2019
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Brazil Banana Case Study

Executive Summary

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Crop: Banana
Location: Brazil
Embrapa Seeds Commercial Biofactories With Breeder Seed of Publicly Released Varieties

- Breeder Seed
  - Demand forecasting and production planning
- Improved Seed
  - 22% improvement
- Foundation Seed
  - 78% improvement
  - Demand forecasting and production planning

Emergence of 6-7% royalty on Embrapa breeding innovations

Ex. Idaho Potatoes
Biofactories Scaled Slowly and Steadily as Operational Issues Were Better Understood and Addressed

In select cases farmers are using positive selection from field and working with laboratories to multiply.

~30 total biofactories producing banana plantlets with ~5-6 leading.
# Organizational Value Chain Leadership Summary

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>VALUE CHAIN ROLE</th>
<th>MAJOR FUNDING SOURCES</th>
<th>FINANCIAL SUSTAINABILITY</th>
</tr>
</thead>
</table>
| **Brazilian Agricultural Research Corporation** | – Varietal Development (Brazilian Banana Breeding program)  
– Maintain Germplasm Active Bank  
– Support MAPA legislation processes | – Government funding  
– Sponsored research  
– Grants  
– PPPs | – Subsidized by public  
– Receive 6% royalties for registered banana hybrids |
| Embrapa | – Certified clean seedling sales and distribution | – Funded through seedling sales  
– Privately owned | – Self-sustaining through revenues of seedling sales |
| **Brazilian Regional Seedling Distributors** | – Develop legislation of micropropagated seed systems  
– Perform regular quality audits at biofactories | – Government funding | – Subsidized by public |
| Campo/ Biocell / Multiplanta / others | | | – Funded by farmer membership and production revenues |
| **Federal Ministry of Agriculture and Livestock** | | | – Subsidized by public |
| MAPA | | | |
| **Farmer Associations** | – Support farmers commercially (guaranteed price for banana fruits)  
– In some cases, facilitate the purchase of TC plantlets through pooled orders to biofactories | – Share of farmer member's production revenues; farmer member fees | |
| Abanorte, Asbanco, Abavar, Frutas Oeste Bahia | | | – Government funding |
| **State Government Organizations** | | | |
| | | | |
| IDAM (Instituto de Desenvolvimento Agropecuario e Florestal Sustentavel do Estado do Amazonas) | | | |

- **FINANCIAL SUSTAINABILITY**
  - Subsidized by public
  - Receive 6% royalties for registered banana hybrids

- **MAJOR FUNDING SOURCES**
  - Government funding
  - Sponsored research
  - Grants
  - PPPs

- **VALUE CHAIN ROLE**
  - Varietal Development (Brazilian Banana Breeding program)
  - Maintain Germplasm Active Bank
  - Support MAPA legislation processes

- **ORGANIZATION**
  - Brazilian Agricultural Research Corporation
  - Brazilian Regional Seedling Distributors
  - Federal Ministry of Agriculture and Livestock
  - Farmer Associations
  - State Government Organizations

- **SUPPORT**
  - Subsidized by public
  - Receive 6% royalties for registered banana hybrids

- **FUNDING SOURCES**
  - Government funding
  - Sponsored research
  - Grants
  - PPPs

- **SUSTAINABILITY**
  - Self-sustaining through revenues of seedling sales
  - Subsidized by public
### Summary of EGS System Success Factors

<table>
<thead>
<tr>
<th>Key Success Factors</th>
<th>Demand Planning &amp; Operations</th>
<th>Enabling Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Financial Sustainability</strong></td>
<td>Growing domestic banana fruit market (with predictable varietal demand &amp; market timing) has given farmers enough experience to reasonably predict demand</td>
<td>Government investment in large production regions and irrigation infrastructure created opportunities for farmer to own and operate land</td>
</tr>
<tr>
<td>Cost reduction strategies supported by data-driven management practices at biofactories ensure an acceptable price for both large and small farmers</td>
<td>Biofactories able to meet demand because of stable varietal preference and advance farmer order norms</td>
<td>National regulations have introduced minimum genetic variation and disease standards for biofactories</td>
</tr>
<tr>
<td>Industry norm in place to share risk of plantlet production through structured contracts with sufficient lead time and staggered payments</td>
<td>Best practices are understood to minimize somaclonal variation and contamination to meet both regulatory requirements and individual biofactory QC standards</td>
<td>Diverse buyers represent a wide customer base for biofactories and makes TC materials accessible to small farmers</td>
</tr>
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<td>Proactive overproduction and over-fulfillment of farmer orders mitigate the anticipated risks of loss due to mutation or contamination</td>
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<td>Farmer associations with both large and small farmer membership offer guaranteed market prices</td>
</tr>
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<td>Emergence of 6-7% royalty on Embrapa breeding innovations</td>
<td>Operational structure of major labs is well defined, with technical staff incentivized to achieve efficiency and quality</td>
<td>Embrapa and biofactories provide materials to support successful transfer of TC materials to farm, and a participatory breeding program is in place for evaluating upcoming varieties</td>
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## Financial Sustainability

### Large, capitalized farmers and irrigation projects enabled initial and continued demand for quality tissue culture (TC) materials at reasonable price

Throughout the 1980s, Brazilian government invested in large-scale irrigation systems to support the development of farmland, leading to attractive growing regions for banana. Beginning in the early 1990s, large, commercial farmers supported the evolution of the banana plantlet demand and enabled biofactories to be successful through large orders of planting materials. This volume allowed labs to have viable business models against their initial costs, but also to scale and improve efficiency enough to eventually support smaller orders from smaller farmers. Today, biofactories have consistent, clear value proposition messaging for farmers about TC planting materials, and the value is generally understood (despite occasional perceived issues of quality or reliability of orders).

### Cost reduction strategies supported by data-driven management practices at biofactories ensure an acceptable price for both large and small farmers

Biofactories are privately owned and operated. Successful biofactories strive to continuously optimize their plantlet production costs, which has resulted in plantlets being affordably priced for farmers. Observed cost optimization strategies include 1) development of highly trained, incentivized and retained staff; 2) detailed analysis of fixed and variable costs such as planting jars (plastic vs. glass) and LED lightbulbs; 3) selection of quality substrate, greenhouse screens, chemicals, media, etc. to minimize losses. As a result of these and other measures, TC material price has remained flat or increased slightly over time, representing only 10-20% of total farmer production costs.

### Industry norm in place to share risk of plantlet production through structured contracts with sufficient lead time and staggered payments

In addition to a relatively stable demand year-over-year, an industry standard exists for contractual agreements between biofactories and farmers. Such contracts are initiated between 4 and 12 months in advance, enabling sufficient lead time for biofactories to produce the necessary plantlets. Typically farmers pay for 30-50% of order when it is placed, and the remaining payment is made after delivery of the materials in 3 or more installments. This practice shares the risk between the two parties and allows flexible financial arrangements based on farmer circumstances.

### Proactive overproduction and over-fulfillment of farmer orders mitigate the anticipated risks of loss due to mutation or contamination

Biofactories proactively initiate ~20% more plantlets than what the farmer orders; by the end of the micropropagation cycle, 3-5% of additional materials are sent to farmers. Biofactories assume there will be loss within the micropropagation process as a result of contamination and mutations. They also assume that there will be minimal material that is not viable after delivery to farmers, either as a result of transportation loss or mutations that are only detectable after further plant growth, so extra materials are commonly sent.

### Emergence of 6-7% royalty on Embrapa breeding innovations

The varieties developed by Embrapa are subject to a 6-7% royalty if registered; an example of this includes BRS Platina, which is multiplied by Multiplanta biofactory. The royalty fee is embedded into the farmer price and not specified as a separate surcharge. The royalties are paid back to Embrapa and support the broader organization, including the breeding program, for further varietal development. For the Embrapa varieties that are not protected, such as BRS Princesa, the plantlets are reproduced and sold without royalty obligations.

### Key Success Factors

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Demand Planning and Operations

At the core, farmers and biofactories have been responding to market demand that has been steadily increasing over the past two decades. The predominantly domestic consumption of bananas (only 2% exported) represents stable preferences of varietal taste and peak market windows. Pricing is also well established by variety, with class differentiation offering a premium for higher-value properties by variety. With relatively feasible transportation by truck and plane to major banana consumption markets (populated cities), farmers can select varieties based on agronomic fit / performance in their respective regions vs. according to specific regional consumer demands.

Large farmers consistently replant 10-20% of their area with TC materials annually, resulting in consistent demand to biofactories. Each biofactory maintains its own clonal gardens that ensure ample supply of mother plants by variety, with consistent proportions of each demanded year over year. As farmer orders are placed at least 4 months in advance, biofactories have sufficient time to adjust their operations according to expected volumes.

Regulatory standards require that TC materials sold to farmers are free from disease contamination and have minimal genetic variation. These standards are met through limiting multiplication cycles and growth regulators and establishing daily morphological evaluations by staff to identify contamination (media plantlets, lab & growth chambers) and mutations (larger greenhouse plants). Additionally, 0.2% of biofactory materials must be sent to virus indexing labs for testing. Customer concerns and complaints, when they occur, are managed through response channels beginning with initial office administrators and escalated to top management as needed.

Today's largest biofactories started small and kept building slowly as organizational knowledge and capabilities grew. Managers knew that maintaining quality and customer satisfaction was critical before more volume growth could be realized. The years of experience and expertise is what large biofactories consider their key differentiator and value proposition against small, new biofactories. Nevertheless, in recent years some major farmers have turned towards smaller/newer labs due to the flexibility they represent and the perception that large operations are at risk of being too large to maintain quality.

Routine daily or weekly production reviews by biofactory management determines whether order fulfilment is on-track, and roles across the organizations are well defined (laboratory and greenhouse activities separately managed and staffed). For major labs (Biocell, Multiplanta), turnover is low with some key managers having 20+ year tenures with the companies. Incentives at multiplication and rooting stages are offered to technicians on a per-plant basis.

A few large progressive farmers are employing positive selection as a technique to have higher control over the characteristics and qualities of their banana production. This process involves selecting the favorable plants in the field and sending those materials to biofactories for multiplication via tissue culture (instead of sourcing from lab’s clonal libraries). While the success of this technique is yet to be proven, it could represent a win-win in that farmers receive materials that are more ideal for their discrete production region/practices and biofactories can offer a custom, differentiated product in which they can charge a premium for multiplication services. Currently between 20-25% of replanted banana material is sourced from TC labs; this method of TC multiplication from farmers’ positive selection has the potential to grow the TC sourced proportion of replanted material against conventional sucker proportion.
Enabling Environment

**Government investment in large production regions and irrigation infrastructure created opportunities for farmer to own and operate land**

Projeto Famoso was a government-funded agricultural land development project in the 1980s originally intended for grains, but evolved into primarily banana production region. As a result of up-front government investment in the irrigation system, the land was viable for production and economic gains. Over time, the ownership shifted to private farmers with varying amounts of land who maintain the land and irrigation schemes through association fees.

**National regulations have introduced minimum genetic variation and disease standards for biofactories**

Disease pressure at various historic points have re-established trust in TC material and made more active government regulation a necessity within the industry. Through these regulations, all TC materials are required to be tested for diseases and meet minimum quality and genetic variation standards. Additionally, three classifications of planting materials were legally defined and provide the framework for multiplication/testing rigor and genetic origin. Given historic issues with previous disease outbreaks, there is now an industry-wide commitment to address the threat of TR4, a fungal disease that is prevalent in virtually all other major banana producing countries.

**Diverse buyers represent a wide customer base for biofactories and makes TC materials accessible to small farmers**

While large farmers play a critical role in the overall demand equation, they do not represent the “typical” Brazilian banana farmer (most banana producers have 15 ha or less). Biofactories offer a range of plantlet sizes and rooting options to meet the demands of farmers with varying circumstances or infrastructure, making the TC plantlet market accessible to small farmers in addition to large. Additionally, in Amazonas state, a government organization (IDAM) supports small farmers by pooling TC plantlet orders.

**Farmer associations with both large and small farmer membership offer guaranteed market prices**

Farmer associations provide commercial price guarantees to farmer members and play a facilitation role in regions where irrigation infrastructure or other community resources are key to production success. These associations are supported through member fees and small surcharges on banana production sold to end markets. In some select cases, associations also support the pooling of orders for TC materials, but this is not their core offering and it usually does not involve smaller farmers.

**Embrapa and biofactories provide materials to support successful transfer of TC materials to farm, and a participatory breeding program is in place for evaluating upcoming varieties**

Farmers are supported through easily-accessible materials from both Embrapa and biofactories regarding best agronomic practices for transferring TC materials to field environments. In some cases, biofactories visit farmers to ensure successful transfer of materials to the field and/or resolve issues related to unsuccessful planting. Select large farmers are also invited to participate in an early-stage participatory breeding program, in which they receive limited amounts of newly developed Embrapa varieties to evaluate in-field (agronomically) and in markets (taste / reception of end customers). This engagement from Embrapa makes TC materials more accessible for all farmers and ensures new varieties can be successful for both farmers and Embrapa.
EGS Seed System Pain Points

Financial Sustainability
Farmer payments for TC planting materials are nearly always staggered in at least 2 installments to address farmer cashflow limitations.

In recent years, farmer trust in TC material has decreased due to perceived or real quality issues in the genetic stability of plantlets. This dissatisfaction in TC materials has caused some farmers to return to conventional planting methods and/or positive selection on a small portion of their farms.

Demand Planning & Operations
Decrease in banana demand in recent years has decreased prices and strained both farmers and biofactories.

Risks of contamination of planting materials is high; leading biofactories have developed rigorous standards to prevent and test for diseases.

Somaclonal variation is a prevalent challenge throughout multiplication process; biofactories customarily send an extra 3% of materials to farmers to accommodate anticipated variation, however, farmers report up to ~20% variation in materials received. By national law, biofactories are allowed to have a maximum of 2.5% of somaclonal variation.

Enabling Environment
Government regulation, verification, and quality assurance oversight are more advanced than in many systems, but in practice, regulatory resource constraints and limited genetic testing from biofactories result in farmer dissatisfaction. There is inspection carried out by Ministry of Agriculture over biofactories but not with high frequency.
**Bioplanta Biofabrica was formed**
- Financed by cigarette company Souza Cruz
- Sophisticated labs and scientists, but unsuccessful at maintaining genetic stability
- Farmers received plantlets with up to 60% variation, felt scammed and wanted to sue but no legislation in place to be able to
- Lasting negative impact on farmer receptivity of tissue culture (TC) material
- Several former employees of Bioplanta went on to create their own labs which are now successful

**Black Sigatoka Fungus hit Brazil**
- Fungus spread rapidly across several banana varieties, primarily located in the north of Brazil
- CAMPO Biofactory generated one million plantlets in a year’s time to salvage production in that region

**Prevalence of on-farm positive selection**
- Because of distrust and dissatisfaction with clonal library TC materials, some large farmers are moving back to conventional planting methods and/or practicing positive selection for TC multiplication

**Re-emergence of TC banana biofactories**
- Large farmer demand / infrastructure and the growing demand of bananas by the market created a new opportunity for biofactories to establish quality protocols in banana plantlet production

**Brazilian legislation developed through Ministry of Agriculture and Livestock (MAPA)**
- Established basic guidelines to be followed for the production, commercialization and use of planting material
- Established more quality control for banana plantlets to ensure mother plants are tested for viruses (Banana Streak Virus & Cucumber Mosaic Virus)

**2019+: Risk of TR4 outbreak in Brazil** may introduce new demand for resistant Embrapa varieties
Market Dynamics
India Dominates Banana Production; Brazil Produces 6% of Global Production

Brazil Ranked 4th Globally for Banana Production in 2016

<table>
<thead>
<tr>
<th>#Country</th>
<th>2016 Production Total (tons)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 India</td>
<td>29,124,000</td>
<td>26%</td>
</tr>
<tr>
<td>2 China (incl. Taiwan)</td>
<td>13,324,337</td>
<td>12%</td>
</tr>
<tr>
<td>3 Indonesia</td>
<td>7,007,125</td>
<td>6%</td>
</tr>
<tr>
<td>4 Brazil</td>
<td>6,764,324</td>
<td>6%</td>
</tr>
<tr>
<td>5 Ecuador</td>
<td>6,529,676</td>
<td>6%</td>
</tr>
<tr>
<td>6 Philippines</td>
<td>5,829,142</td>
<td>5%</td>
</tr>
<tr>
<td>7 Angola</td>
<td>3,858,066</td>
<td>3%</td>
</tr>
<tr>
<td>8 Guatemala</td>
<td>3,775,150</td>
<td>3%</td>
</tr>
<tr>
<td>9 Tanzania</td>
<td>3,559,639</td>
<td>3%</td>
</tr>
<tr>
<td>10 Rwanda</td>
<td>3,037,962</td>
<td>3%</td>
</tr>
<tr>
<td>11 Costa Rica</td>
<td>2,409,543</td>
<td>2%</td>
</tr>
<tr>
<td>12 Others</td>
<td>28,318,900</td>
<td>25%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>113,537,864</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

SOURCE: FAOSTAT

Bananas are produced throughout Brazil, but highest in Southeast and Northeast

SOURCE: Embrapa Database
Top Brazilian Banana Production Regions

### 2017 Area Harvested by Brazilian State (hectares)

<table>
<thead>
<tr>
<th>State</th>
<th>Area Harvested (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahia</td>
<td>72,584</td>
</tr>
<tr>
<td>Sào Paulo</td>
<td>49,012</td>
</tr>
<tr>
<td>Pará</td>
<td>43,145</td>
</tr>
<tr>
<td>Minas Gerais</td>
<td>41,525</td>
</tr>
<tr>
<td>Pernambuco</td>
<td>40,399</td>
</tr>
<tr>
<td>Ceará</td>
<td>40,029</td>
</tr>
<tr>
<td>Santa Catarina</td>
<td>29,145</td>
</tr>
<tr>
<td>Espírito Santo</td>
<td>25,020</td>
</tr>
<tr>
<td>Goiás</td>
<td>13,719</td>
</tr>
<tr>
<td>Rio Grande do Sul</td>
<td>11,854</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>11,382</td>
</tr>
<tr>
<td>All Others*</td>
<td>87,620</td>
</tr>
</tbody>
</table>

#### Total area harvested = ~475,000 ha

- ~300,000 ha formally produced; remainder is smallholder, backyard, informal production

*Includes states with less than 10,000 harvested hectares

**SOURCE:** Embrapa Database

**Notes:**
- States harvesting more than 10,000 hectares in 2017
- States harvesting less than 10,000 hectares in 2017

*62% of Brazilian Banana Production*

*81% of Brazilian Banana Production*
Banana Yield Continues to Improve; Harvested Area peaked in 1997

Brazil Banana Harvested Area and Yield

[Graph showing harvested area and yield from 1985 to 2017]
Domestic Demand has Increased Over Time with Population Growth; Very Little Banana Export

Historically, less than 2% of Brazilian bananas are exported each year due to:

Production and Quality Issues:
Including post-harvest handling, transportation issues, and issues with flesh color from colder weather, high labor costs

Varietal Preference:
Cavendish is the world’s most popular variety and Brazil mostly produces other varieties which are not demanded by the U.S. (the world’s largest banana importer)

Brazil Population and Banana Production & Consumption
# Most Common Brazilian Banana Varieties

<table>
<thead>
<tr>
<th>% Brazilian Production</th>
<th>PRATA</th>
<th>PACOVAN</th>
<th>CAVENDISH</th>
<th>BR PRINCESA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>~50%</td>
<td>&lt;10%</td>
<td>~40%</td>
<td>&lt;10%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Market Window (Best time to sell)</th>
<th>PRATA</th>
<th>PACOVAN</th>
<th>CAVENDISH</th>
<th>BR PRINCESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar</td>
<td>N/A</td>
<td>Jun-Aug</td>
<td>N/A</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Average Yields</th>
<th>PRATA</th>
<th>PACOVAN</th>
<th>CAVENDISH</th>
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<tr>
<td>~35 MT / ha</td>
<td>~20-25 MT / ha</td>
<td>~70 MT / ha</td>
<td>~30 MT / ha</td>
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<table>
<thead>
<tr>
<th>Typical Market Price (2018)</th>
<th>PRATA</th>
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<tr>
<td>R$1.12/KG or ~US$294/MT</td>
<td>R$30-70 / one hundred bananas</td>
<td>R$0.76/KG or ~US$199/MT</td>
<td>R$0.35/KG</td>
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<th>Most Common Cultivars / Other Notes</th>
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<td><strong>PRATA</strong></td>
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<td>~Most common cultivars</td>
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<tr>
<td>– Prata Ana (Natural variation; recommended by Embrapa in early 1980s)</td>
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<tr>
<td>• Stable production YOY</td>
</tr>
<tr>
<td>• Highly synchronized</td>
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<tr>
<td>– Prata Catarina</td>
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<td>All Prata cultivars sold for same price to end market; separated by 1st and 2nd quality class</td>
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<td>Produced &amp; consumed throughout Brazil</td>
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Hortifrutti/Cepea; Farmer Interviews; Embrapa
Main Banana Diseases/Challenges in Brazil

**Fungi**
- **Fusarium Wilt Race 1** (Panama Disease)

**Viruses**
- Cucumber Mosaic Virus
- Banana Streak Virus

**Fusarium Wilt Race 4**
- Not yet in Brazil, but expected to be a future threat; EMBRAPA breeders already testing a resistant variety

**PeSTS**
- Cosmopolites soridus
- Nematodes
Leadership
Organizational Leadership by Value-Chain Step

~30 total biofactories producing banana plantlets with ~5-6 leading

Small Farmers
Farm of Marcos Ribeiro

Embrapa

Biofactories

In select cases farmers are using positive selection from field and working with laboratories to multiply

Breeder

Basic or Certified Seed

Seed Multiplication

Production
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- Perform regular quality audits at biofactories | - Government funding | - Subsidized by public |
| Federal Ministry of Agriculture and Livestock | - Support farmers commercially (guaranteed price for banana fruits)  
- In some cases, facilitate the purchase of TC plantlets through pooled orders to biofactories | - Share of farmer member's production revenues; farmer member fees | - Funded by farmer membership and production revenues |
| Farmer Associations | - Pool orders for small farmers in the north of Brazil | - Government funding | - Subsidized by public |
| State Government Organizations | | | |
| IDAM (Instituto de Desenvolvimento Agropecuario e Florestal Sustentavel do Estado do Amazonas) | | | |
Organizational Leadership by Value-Chain Step

In select cases farmers are using positive selection from field and working with laboratories to multiply.
MISSION
To design research, development and innovation solutions for the sustainability of Brazilian agriculture for the benefit of the Brazilian society.

INSTITUTIONAL PROFILE
Established in 1973
Linked to Ministry of Agriculture, Livestock and Food Supply
9,807 employees
2,444 researchers
B.Sc. 1%
M.Sc. 15%
D.Sc./Ph.D. 84%

Embrapa – Brazilian Agricultural Research Corporation

Embrapa Operates 42 Decentralized Centers of Research and Services
Embrapa – 42 Decentralized Centers of Research and Services

- **Embrapa HQ**
- **08 Thematic Centers**
- **15 Product Centers**
- **17 Eco-Regional Centers**
- **02 Services Centers**
Embrapa – National Center for Cassava and Tropical Fruit Research (Bahia State, Brazil)

MISSION: To provide solutions for the sustainable development of the cassava and tropical fruit crops agribusiness by generation, adaptation and transfer of knowledge and technologies for social benefit

The National Center for Cassava and Tropical Fruit Research is based in Bahia State, Brazil, but is mandated to serve all of Brazil

Established in 1975
Total Area: 262 ha
227 employees
71 researchers

SOURCE: SGP/CNPMF, Oc.2014
In select cases farmers are using positive selection from field and working with laboratories to multiply.
Banana Biofactories Provide Clean Seedlings Throughout the Country

Brazilian Banana Biofactory Locations

The number of BANANA BIOFACTORIES INCREASED BY 112.5% from 2008 to 2016. Volume rose from 16 banana biofactories to 34 in 2016.

Only FIVE BIOFACTORIES produce BANANA SEEDLINGS EXCLUSIVELY. 29 of the banana biofactories also PRODUCE OTHER SPECIES.

Brazil produced around 7.5 MILLION SEEDLINGS BY TISSUE CULTURE in 2010; today, an estimated 10-12 MILLION TC SEEDLINGS are produced.

SOURCE: Panorama da producao de Mudas Micropropagdas no Brasil (2008-2015); received from Embrapa contact
<table>
<thead>
<tr>
<th>BIOFACTORY</th>
<th>LOCATION</th>
<th>FOUNDING YEAR</th>
<th>ESTIMATED # BANANA PLANTLETS PRODUCED ANNUALLY</th>
<th>FARMER PRECEPTIONS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocell</td>
<td>Sete Lagoas-Minas Gerais</td>
<td>2000</td>
<td>3.5M</td>
<td>Generally higher priced plants, some problems with variation in more recent orders.</td>
</tr>
<tr>
<td>CAMPO</td>
<td>Cruz das Almas-Bahia</td>
<td>1991</td>
<td>0.6M</td>
<td>Positive perception – good quality, good price.</td>
</tr>
<tr>
<td>Multiplanta</td>
<td>Andradas-Minas Gerais</td>
<td>1991</td>
<td>3.0M</td>
<td>Generally higher priced plants, some problems with variation and timely delivery. Material generally high quality.</td>
</tr>
<tr>
<td>FLORA</td>
<td>Itajai-Santa Catarina</td>
<td>2008</td>
<td>0.7M</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Ilheus-Bahia</td>
<td>1997</td>
<td>&lt;0.5M</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Amador, Eusebio-Ceara</td>
<td>2008</td>
<td>&lt;0.5M</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Holambra-Sao Paulo</td>
<td>2005</td>
<td>&lt;0.5M</td>
<td>N/A</td>
</tr>
<tr>
<td>COSTA RICA</td>
<td>Multiple biofactories (Cavendish only)</td>
<td>N/A</td>
<td>N/A (multiple biofactories)</td>
<td>Considered better material than Brazil; pay R$3.80/plantlet + transportation. In beginning, up to 50% of materials lost during transportation (dehydration); Now don't lose anything.</td>
</tr>
</tbody>
</table>

*Qualitative assessment from limited number of farmer interviews; N/A indicates that a farmer customer of that biofactory was not interviewed.
TC Plantlets are Estimated to Make Up at least ~20-25% of Replanted Banana Area Annually

<table>
<thead>
<tr>
<th>Estimated # TC Plantlets produced &amp; sold per year</th>
<th>11,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ha Banana in Brazil</td>
<td>465,000</td>
</tr>
<tr>
<td># Plantlets/Ha</td>
<td>1600</td>
</tr>
<tr>
<td>Avg Duration of Plant (yrs)</td>
<td>15</td>
</tr>
<tr>
<td>% Plants replaced annually</td>
<td>7%</td>
</tr>
</tbody>
</table>

| Ha replanted annually                            | 31,000     |

| TOTAL # Plants needed to replant annually (Conventional + TC) | 49,600,000 |

| % Replanting by TC plantlets                      | ~22%       |
| % Replanting by Conventional/Saved Seeds          | ~78%       |

<table>
<thead>
<tr>
<th>Estimate based on bottom-up sum of major banana biofactories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates based on industry expert opinions</td>
</tr>
<tr>
<td>Supplied by biofactories (low estimate)</td>
</tr>
<tr>
<td>Replanted on farm through conventional methods</td>
</tr>
</tbody>
</table>
### Micropropagation Technique Overview

<table>
<thead>
<tr>
<th>Phase 1: Initiation</th>
<th>Phase 2: Multiplication</th>
<th>Phase 3: Rooting</th>
<th>Phase 4: Acclimatization</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lateral buds from root suckers are sterilized and placed into culture media</td>
<td>Genetic stability kept through controlled number of multiplication cycles and controlled concentration of growth regulators</td>
<td>Prepare plants for rooting through reducing cytokinin concentration, using a double layer of medium, and using ethylene inhibitors</td>
<td>Shift plants from culture medium into artificial substrate</td>
</tr>
<tr>
<td>Extract portion of leaf to be virus indexed with molecular tools (usually by public universities, some private companies, which also need MAPA certification)</td>
<td>Lower % contamination</td>
<td>Shift from heterotrophic to autotrophic conditions – stress plants before moving to aid in acclimatization in natural conditions</td>
<td>High humidity initially, then gradually reduce</td>
</tr>
<tr>
<td>High % of contamination</td>
<td>Biorreactors – previously common tool to increase multiplication, but today limited use because high instance of contamination</td>
<td>Sampling for virus indexing</td>
<td></td>
</tr>
</tbody>
</table>

- **Phase 1: Initiation**
  - The lateral buds from root suckers are sterilized and placed into culture media.
  - Extract portion of leaf to be virus indexed with molecular tools (usually by public universities, some private companies, which also need MAPA certification).
  - High % of contamination.

- **Phase 2: Multiplication**
  - Genetic stability kept through controlled number of multiplication cycles and controlled concentration of growth regulators.
  - Lower % contamination.
  - Biorreactors – previously common tool to increase multiplication, but today limited use because high instance of contamination.

- **Phase 3: Rooting**
  - Prepare plants for rooting through reducing cytokinin concentration, using a double layer of medium, and using ethylene inhibitors.
  - Shift from heterotrophic to autotrophic conditions – stress plants before moving to aid in acclimatization in natural conditions.

- **Phase 4: Acclimatization**
  - Shift plants from culture medium into artificial substrate.
  - High humidity initially, then gradually reduce.
  - Sampling for virus indexing.
Campos Biotecnologia Vegetal Ltda, a national company with private capital, was created in 1991 in Paracatu-MG with the mission of offering Brazilian farmers high quality seedlings that meet the competitive quality standards of the national and international market; thus contributing to sustainable agriculture from the social, economic and environmental point of view through the application of the tools of modern biotechnology.

Entered partnership with Embrapa and Bahian Agricultural Development Company (EBDA) in 1998 to create the biofabrica in Cruz das Almas.

100% of Cruz das Almas plantlet production is banana; sell to farmers throughout the country.

In 2001, created CAMPO da Amazonia in Manaus-Amazonas to meet demand for disease resistant bananas in the Northern region. It is an acclimatization facility that sells banana plantlets that are ready for field planting.

Location:
Cruz das Almas-Bahia

Manaus-Amazonas

CAMPO Visit – Macropropagation Demonstration – not done often by labs or farmers

1. Extract suckers (can be done without destroying original plant or bunch)
2. Check for disease/pest symptoms, plant with knob facing down
3. First plant will not produce good bunch; used as mother plant only
4. At 6-7 months old (before producing bunch), take off suckers, ensure no disease, wash with chloride
5. Upon rooting in ~60 days, kill meristem which induces later buds, then kill lateral buds to induce second lateral buds
6. Can produce 50-100 plantlets in 1 year

Process is similar to PIBS (Plants Issus de Bourgeons Secondaires), a rapid multiplication technique applied to plantain

---

**PROS**
- Does not require sterile conditions
- Easier to maintain than biofactory

**CONS**
- More susceptible to disseminating pests and diseases vs. TC materials
- High infrastructure / facilities / labor / expertise required
- Inconsistent / potentially low propagation factors

**WHY IT IS NOT COMMONLY USED IN BRAZIL**

The technical labor and intensity to do macropropagation in the growing region has not been able to substantiate a benefit as compared to the affordable and well-established micropropagated TC options.
Marcio de Assis, Owner & Administrator

Multiplanta

Location: Andradas-Minas Gerais

Established in 1991

~45 employees
(including 2 lab supervisors, 1 greenhouse supervisor, and 2 office administrators)

6 hectares, 17,000 m² of greenhouses

~65% of plantlet production is banana; other crops include strawberry, potato and eucalyptus

2003

Law 10711

Defines THREE classes of plantlets
(All three are common; non-certified does not represent poor quality)

1 Non-certified without genetic origin
Clones collected from field – Technical report required to prove it is virus free

2 Non certified with genetic origin
Cones provided by Empraba

3 Certified
Certified and documented according to standards of MAPA, free to be marketed to all Brazilian states and abroad

Multiplanta is the only biofactory that produces Class 3 Certified banana plantlets

Marcio considers this classification as a business decision to avoid conflict and eliminate risks; some incremental costs but never considered eliminating
“No Excuses” Philosophy

Laboratories have enough experience to resolve production/quality issues and should no longer have technological shortcomings
- Errors (late delivery, incorrect orders, mutations, etc.) are a result of human oversight, not lack of capabilities or technology
- Clear incentives must be provided to staff to ensure efficiency and quality; Maximum of 7 multiplication cycles

Farmers have access to multiple sources of support from both Multiplanta & Embrapa
- Embrapa routinely publishes articles and information on how to successfully transfer TC to field
- Multiplanta also provides instructions to farmers, and for the complaints received (5-10% orders), most issues are agronomic, not technological
### Multiplanta

**ORDERING & DEMAND PLANNING PROCESS**

- Multiplanta plants new materials everyday with anticipated demand
- Farmer advance orders
  - For large orders (40,000+ plantlets), require 4-5 months notice
  - For smaller orders (<40,000), 2 months is usually sufficient
- 30% payment made up front; the remainder in installments after delivery
- Use computer tracking to monitor order progress daily
- Transportation of materials enabled by robust trucking and air cargo network and paid for by farmers

**CLONAL GARDEN MANAGEMENT**

- On-site clonal garden contains a range of cultivars (~40% Cavendish, ~40% Prata, ~20% Silk/BRS Princesa/other)
- Clones are analyzed every 3 years (tested for virus, replaced as needed based on new materials available)
- Several varieties are registered and royalties are paid
  - **Conquista** – discovered & developed in the Amazon
  - **Platina** – Embrapa variety; 7% royalties paid
  - **BRS Princesa** – Embrapa variety; no royalties paid because not registered

### LARGE PLANTLETS
- Field ready, less durable transportation
- ~60% business
- 3% additional plantlets sent to farmers
- Sold in 24 unit trays
- Sold for R$2.10 / plantlet

### SMALL PLANTLETS
- Not field ready, more durable transportation
- ~40% business
- 5% additional plantlets sent to farmers
- Sold in 98 unit trays
- Sold for R$1.70 / plantlet

**CONTEXT**

http://www.multiplanta.com.br/
Biocell

BIOCELL is a private Brazilian company of Plant Biotechnology whose main social objective is to commercialize seedlings of plants of commercial interest, produced through the process of micropropagation in the laboratory, using modern techniques of Tissue Culture “in vitro”.

**Location:**
Sete Lagoas-Minas Gerais

**Established in 2000**
**Produce ~3.5M plantlets annually (>90% banana)**
**4 ha, with plans to expand to 6 ha in coming years**
**50 employees**
### Biocell – Key Elements of Business

<table>
<thead>
<tr>
<th>Sell 100% to large farmers through long-term contracts</th>
<th>Minimize risk of contamination and variation</th>
<th>Continuously evaluate and reduce costs</th>
<th>Traceability and continuous monitoring of plantlet production progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Edilson’s view, Biocell was and is successful because large farmers had/have scale, infrastructure and knowledge for using TC plantlets</td>
<td>Train staff to carefully identify and remove contaminated materials and somaclonal variations</td>
<td>Biocell switched from glass to plastic jars, and also invested in efficient, durable LED lights in growth chambers</td>
<td>All materials are labeled and traced clearly (stage, variety, technician, hood #); currently manually but in the process of adopting a computerized system</td>
</tr>
<tr>
<td>Set expectation for placing orders at least 1 year in advance; 30% paid in advance and 70% paid in 3 installments after delivery of materials</td>
<td>Multiply a maximum of 10 cycles to minimize somaclonal variation; train staff to identify and remove out variance in greenhouse stage</td>
<td>Techniques and training of new employees are focused on minimizing contamination and maximizing efficiency; low turnover</td>
<td>Weekly status check of order progress to ensure timely production and preemptive communication of issues to customers</td>
</tr>
<tr>
<td></td>
<td>Produce an additional 20% of plantlets, send 3% extra to the farmer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Signs of somaclonal variation include** yellow discoloration, asymmetrical leaves, waxy leaves, etc.
## Biocell – Three Types of Plantlets Sold

<table>
<thead>
<tr>
<th></th>
<th>Small Bare Root</th>
<th>Medium in Substrate</th>
<th>Large in Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Biocell Business</td>
<td>~2%</td>
<td>~30%</td>
<td>~70%</td>
</tr>
<tr>
<td>Price per plantlet</td>
<td>R$0.80</td>
<td>R$1.60 – R$1.80</td>
<td>R$1.90 – R$2.10</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Require sophisticated farmer</td>
<td>Not yet ready for field –</td>
<td>Ready for field</td>
</tr>
<tr>
<td></td>
<td>knowledge and greenhouses;</td>
<td>require acclimatization prior to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farmers must sign contract</td>
<td>planting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>accepting liability for plantlets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In select cases farmers are using positive selection from field and working with laboratories to multiply.
## Overall TC Complaints from Farmers

<table>
<thead>
<tr>
<th>Lack of varietal consistency</th>
<th>Farmers claim to receive incorrect materials from what was ordered (ex: Prata Ana instead of Prata Catarina)</th>
<th>Within a single variety, farmers experience a high degree (15% or more) of somaclonal variation in the TC materials, even though Brazilian regulations set a maximum of 2.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of disease control</td>
<td>Farmers claim to receive TC plantlets that are not free from Panama disease, even through Brazilian regulations require biofactories to test for diseases</td>
<td></td>
</tr>
<tr>
<td>Lack of uniformity</td>
<td>Due to natural variation and/or packaging, plantlets often arrive with a range of heights and maturity within a single product type (“large” vs “small” as defined by TC labs)</td>
<td></td>
</tr>
<tr>
<td>Unreliable delivery</td>
<td>Delayed delivery of TC materials results in farmers missing the ideal market windows</td>
<td></td>
</tr>
<tr>
<td>Uncertain plantlet lifespan</td>
<td>The ROI of the planting material is inconsistent and unpredictable</td>
<td>While some TC materials have had strong in-field banana production for 20+ years, others have quit producing bananas after 4 years.</td>
</tr>
</tbody>
</table>
**Farmer Demographics**

<table>
<thead>
<tr>
<th># HECTARES</th>
<th>LARGE FARMERS</th>
<th>SMALL FARMERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;15 ha</td>
<td></td>
<td>&lt;15 ha</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% BRAZIL PRODUCTION</th>
<th>LARGE FARMERS</th>
<th>SMALL FARMERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10%</td>
<td></td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>LARGE FARMERS</th>
<th>SMALL FARMERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clustered in large banana-producing regions of Brazil, including Sao Paulo, Bom Jesus da Lapa, Delfinópolis, and Northern Minas Gerais</td>
<td></td>
<td>Throughout Brazil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TC PLANTLET ADOPTION</th>
<th>LARGE FARMERS</th>
<th>SMALL FARMERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have greenhouse / nursery infrastructure near farms to enable the purchase of smaller TC plantlets (acclimatization)</td>
<td></td>
<td>More commonly buy larger TC plantlets that can be planted directly to the field</td>
</tr>
<tr>
<td>TC plantlets used at a higher rate (~10-20% of area)</td>
<td></td>
<td>TC plantlets used at a lower rate (&lt;10% area if at all); additional replanting done conventionally</td>
</tr>
</tbody>
</table>

*Of farmers with less than 6 ha, ~1% use tissue culture*
# Large Farmer Techniques

<table>
<thead>
<tr>
<th>Greenhouse / Nursery On-Farm</th>
<th>On-farm positive selection</th>
<th>Over-planting &amp; elimination</th>
<th>Integrated Pest Management against Panama disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase smaller plantlets from biofactory and acclimate on-farm in greenhouse</td>
<td>Select plants w/ favorable bunches, synchronization, disease resistance, etc.</td>
<td>Example: Plant 3x1m (3334 plants/ha) and eliminate the weakest plant → 3x2m (1667 plants/ha)</td>
<td>Nutrition (but w/ risk of fusarium spread)</td>
</tr>
<tr>
<td>Use soil, organic matter &amp; manure to plant in pots, then into the ground after 1-2 months</td>
<td>Send mother plant materials to labs for multiplication</td>
<td></td>
<td>Trichoderm (micro organism / fungus-antagonist to fusarium)</td>
</tr>
<tr>
<td>Irrigated and treated with biofertilizer and chemical treatments</td>
<td></td>
<td></td>
<td>Liming pH control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bacillus subtilus and bacillus protogen</td>
</tr>
</tbody>
</table>
Large Farmers – Greenhouse Nursery

Large Farmer Nelson Jr. and his On-Farm Nursery in Bom Jesus da Lapa – BA

Farmer coalition in Jaiba – MG constructed a greenhouse to support their 400 ha operation after frustrations with high loss during acclimatization

Plantlets treated with nutritional blend (both biofertilizer and chemical treatment) through overhead irrigation

Some plantlets potted in manure mixture, others with soil/organic matter mixture, until transplanted to field

Positively select mother plants from their fields for multiplication by Flora Biofactory (buy for R$1.50/plantlet), then plantlets acclimated in greenhouse for 50-70 days before planting

Experiencing <1% loss in greenhouse; receive support from Flora lab technicians

Would consider selling to local small farmers after operation scales; would charge R$2.00-2.10/plantlet (margin of at least R$0.50)
The agronomists and technicians are looking for several key characteristics during positive selection process:

Yield & Uniformity of Bunch
- Larger bunches improve yield; More uniform bunches offer improved handling, cutting and shipping

Synchronization of 2nd and 3rd stems
- The timing and synchronization of the second & third stem impacts the consistency of harvests; ideally the second stem can be harvested 2-3 months after first

Disease Resistance
- Mother plant must be resistant to Panama disease

Others
- Shorter plants
- Straightness of banana fruit fingers
- Fruit that do not ripen in the field

It typically takes at least 3 cycles for the positively selected materials to stabilize; the consistency and true benefits of positive selection are still unclear / unproven
Brasnica (Fazenda Oriente)

Brasnica sources **all of its new planting materials from TC labs** (mostly CAMPO and Multiplanta) due to disease pressure

- Out of its 2400 ha, the company plants about 50 ha of new material annually, or ~2% (a large area was planted in 2012 and therefore is not yet part of the replacement cycle)
- Conventional re-planting is only done in the case of TC plantlet failure (~5% of the time)

Brasnica has considered **investing in their own biofactory**, but the high investment and specialization required has deterred the decision to date

**Demand by variety** is determined by centralized Brasnica management based on market expectations and trends; each farm is then given the directive on what and how much to plant

Brasnica **exports part of its BRS Princesa banana production to the United States** (first Embrapa variety to be exported)

---

**THE COMPANY’S BANANA PRODUCTION IS 100% ORGANIC**

- All TC materials were originally sourced as naked root to abide with organic certifications for limited substrate (today allowed small amount of substrate)
- Avoid chemical treatments for disease control, relying solely on organic treatments (bacillus)

http://www.brasnica.com.br/
Brasnica (Fazenda Oriente)

Total Brasnica Banana Area = 2400 ha

- Tocantins, 200
  - Delfinopolis, 600
- Janauba / Jaiba Area, 1600

**Fazenda Oriente** = 116ha or ~5% of Brasnica banana area

- Prata = ~60 ha
- Cavendish = ~20 ha
- Princesa = ~30 ha

TC plants acclimated in a regional greenhouse close to Fazenda Oriente (shared by several Brasnica farms near Jaiba)

Location: Jaiba-Minas Gerais
Borborema Farms

Borborema farms was **established in early 1990s; produce primarily bananas**, but also mangos, papayas and other fruits.

Current production is in Jaiba-Minas Gerais across **four farms totaling 750 hectares**; Expansion is underway to add **400 hectares** to the operation, located in Montes Claros-Minas Gerais.

Source banana plantlets (multiplied entirely from their **positively selected mother plants**) from **small labs**; prefer small labs because of perception that large labs have lost quality and consistency in material as they scaled.

Borborema is **exploring the possibility of exporting bananas**, but do not currently export due to the regulatory burden and uncertain economic benefits.

Instead, the strategy is to **shift production closer to major Brazilian cities** for easier transport to domestic markets.

Borborema is aware of **climate changes’ effects**. The north of MG is extremely hot during summer which reduces yields in the banana plants. One option Borborema is considering is moving to places where temperatures are not so high, such as Delfinópolis – MG.

**Location:**
Jaiba-Minas Gerais
Due to low satisfaction and reliability with TC planting materials from large labs’ clonal libraries, Borborema has established a partnership with three small biofactories to multiply their own positively selected planting materials. Borborema pays a premium of R$1.75/plantlet for the positively-selected plantlets, which includes the technical support. (Cost of TC material from clonal libraries would be ~R$1.40)
Farm of Marcos Ribeiro

380 banana hectares currently with plans to expand to 500 ha total

- Primarily Prata Gorutuba
- Small area of BRS Princesa

Replants ~10% annually with TC materials

Does positive selection of field plants (managed by a single agronomist) and sends to CAMPO Biofactory for multiplication

Pays R$2.10/plantlet for replicated mother plant material

Location: Jaiba-Minas Gerais
Small Farmers

GOVERNMENT: INPUT PURCHASE SUPPORT

Government involvement in TC orders is most prevalent in Amazonas state, where farms are smaller and less specialized.

In Amazon region, farmers / organizations are buying plantlets from biofactories and having them shipped to their region (minimal incremental cost: ~R$150 for large box).

In this region, intercropping bananas with acai, palm, guarana, etc. is common, so farmers are less specialized in banana as compared to the Central and Southern regions of Brazil.

ASSOCIATIONS: COMMERCIAL SUPPORT

Farmer cooperatives / associations negotiate banana fruits’ market price for small + large farmers.

While this banana fruits’ market price guarantee is beneficial during off-market window periods, it can mean that small farmers receive much lower prices during peak market.

Example: One small farmer interviewed is member of Abanorte Association. At time of visit, national price for Cavendish was R$0.70/kilo, but he was only receiving R$0.40/kilo.

In some select cases, associations support the pooling/purchases of TC orders, but this is typically among larger farmers vs. smaller.
Small Farmers

ELADIO SANTOS LIMA, 15 ha farmer

Technical background: ag technician, formerly worked in forestry

Uses TC material on 70-80% of replanting, but has experienced issues with disease, variation, and size of plantlets received (too small, so needed to assemble makeshift screenhouse to grow and acclimate before planting)

No aggregate view of farm budgets, but could build up to estimates based on input costs and pricing

Small farmers’ biggest challenges are how to cope with high prices of inputs, which are determined in US Dollars. The prices payed for banana fruits are in Brazilian Reais, and in recent years, prices have decreased.

CARLOS HENRIQUE CARDOSO, 6 ha farmer

Non-technical background; farm handed down through generations

Does not use TC material; only replants conventionally

No aggregate view of farm budgets, but could build up to estimates based on input costs and pricing

Member of Abanorte association which ensures guaranteed pricing of bananas

4 employees
Bananas are Classified by Genomic Groups and Subgroups

The Main Banana Cultivars (and their Genomic Groups) in Brazil Include:

<table>
<thead>
<tr>
<th>Genomic Group</th>
<th>Cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Ouro (AA), Nanica (AAA), Nanicão (AAA), Great Naine (AAA)</td>
</tr>
<tr>
<td>AAA</td>
<td>Maca (AAB), Mysore (AAB), Prata (AAB), Pacovan (AAB), Dwarf Prata (AAB), Terra (AAB), D’Angola (AAB), Fig (AAB)</td>
</tr>
<tr>
<td>AAB</td>
<td>Includes Cavendish varieties</td>
</tr>
</tbody>
</table>

Plants of the AA genomic group are usually thin, presenting pseudostem with many dark spots and leaves erect and narrow, with the base of the open petiole.

The plants of the AAA genomic group are similar to group AA, usually more vigorous, presenting dark on the pseudostem, petioles with open base and pigmentation opaque on the inner face of the male bracts.

The plants of the AAB genomic group present, generally, few dark spots on the pseudostem, petioles with margins erect and bright pigmentation on the inner side of the male bracts.

Each genomic group exhibits differentiating characteristics in taste, look, and feel.

Bananas Grown in Brazil are “Dessert” Varieties:

<table>
<thead>
<tr>
<th>Northern Varieties:</th>
<th>Southeastern Varieties:</th>
<th>Southern Region:</th>
<th>Midwest Region:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacovar, Prata, Terra (Plantains) (AAB varieties)</td>
<td>Prata, Dwarf Prata, Maca (AAB varieties) &amp; Cavendish (AAA variety)</td>
<td>Cavendish and Prata</td>
<td>Prata and Maca</td>
</tr>
</tbody>
</table>

SOURCE: Brazilian Banana Crop: Current Situation and Research Challenges; Embrapa 500 Questions, 500 Answers
<table>
<thead>
<tr>
<th>Variety</th>
<th>Launched</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana BRS SCS Belluna</td>
<td>2016</td>
<td>Indicated for fresh and processed consumption, especially for flour and dehydration. Recommended for planting in Santa Caterina and has been adopted by several growers in that state.</td>
</tr>
<tr>
<td>BRS Japira</td>
<td>2010</td>
<td>Recommended for growers in North &amp; Northeast regions, and North of Minas Gerais. Has been key in restoring the viability of banana farming in the Northern region of the country.</td>
</tr>
<tr>
<td>BRS Princesa</td>
<td>2010</td>
<td>Good disease tolerance and is recommended to replace some issues growers face with the Maca cultivar, including increased consumer demand and disease susceptibility.</td>
</tr>
<tr>
<td>BRS Platina</td>
<td>2012</td>
<td>Exhibits high qualities that command the highest marketing classification. Meets consumer demand for Prata type bananas in areas that Prata Ana is limited by disease.</td>
</tr>
<tr>
<td>BRS Vitoria</td>
<td>2005</td>
<td>50% average increase in productivity in regions that grow traditional banana varieties. Fully meets demand in the State of the Amazonas.</td>
</tr>
</tbody>
</table>

Embrapa Hybrid Variety Development:

Embrapa receives 6% royalties for any licensed varieties.

SOURCE: Embrapa
Embrapa Hybrids (cont.)

Garantida
Pacovan Ken
Preciosa
Pioneira

Tropical
Caprichosa
Pacoua

Cultivars
Prata-Anã
Pacovan
# Embrapa’s Expertise and Breeding Effort by Variety

<table>
<thead>
<tr>
<th></th>
<th>Prata</th>
<th>Silk (Maca)</th>
<th>Cavendish</th>
<th>Gros Michel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge</strong></td>
<td>High</td>
<td>Intermediary</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Crosses/seeds</strong></td>
<td>Frequent</td>
<td>Difficult</td>
<td>More difficult</td>
<td>More difficult</td>
</tr>
<tr>
<td><strong>Effort/work</strong></td>
<td>Medium</td>
<td>High</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td><strong>Time to results</strong></td>
<td>Medium</td>
<td>Long</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td><strong>Budget</strong></td>
<td>$$</td>
<td>$$</td>
<td>$$$$$$$</td>
<td>$$$$</td>
</tr>
<tr>
<td><strong>Impact</strong></td>
<td>High</td>
<td>Very high</td>
<td>Extremely high</td>
<td>Extremely high</td>
</tr>
<tr>
<td><strong>Consumers</strong></td>
<td>Brazil/Australia</td>
<td>Brazil/Africa</td>
<td>World</td>
<td>World again</td>
</tr>
</tbody>
</table>

*Amorim, 2017*
Embrapa’s Breeding Strategy has Several Focus Areas

- Chromosome doubling
- Drought tolerance
- Fruit ripening
- In vitro fertilization
- Avoid finger drop
- Molecular markers
- Germplasm conservation
- Somaclonal variation
Fusarium race 4 (TR4) is a looming threat for Brazil as it is already prevalent in many banana-producing regions. Embrapa is proactively breeding resistant cultivars.

Embrapa is already testing its TR4-resistant hybrids in Australia.
Embrapa Participatory Breeding Program with Farmers is a Key Part of Their R&D Program

BANANA BREEDING PROGRAM FOR NEW VARIETAL DEVELOPMENT & TESTING

Stage 1: Evaluation in Cruz das Almas (agronomic and taste testing)
Stage 2: Large farmer participatory breeding
Stage 3: Further evaluation by Embrapa & large farmers

~30 Farmers across two key banana regions are provided 100 plants of region-specific hybrids to evaluate for 2 years

After testing period, farmers provide feedback to Embrapa on both agronomic characteristics and market/end user receptiveness

Northern Minas Gerais
Borborema • Brasnica • Marcos Ribeiro

South (Santa Catarina & Rio Grande do Sul)
Material sent to ASBANCO (Association of banana growers in Corupá), which is distributed across 5 producers
Embrapa Played a Key Role in Developing DATAMusa

In 2002, to preserve bananas as a KEY FOOD SOURCE in Brazil, Embrapa encouraged collaboration between national and international organizations.

This collaboration would employ RESEARCH ON GENOMICS AND BIOTECH to find solutions to issues with disease, insects, and the growing environment.

The initial research project was funded by Conselho Nacional de Desenvolvimento Científico e Tecnológico.

The research project resulted in the CREATION OF DATAMusa, the database where all of the genomics information is housed.

DATAMusa is the SECOND LARGEST DATABASE of BANANA GENOMICS in the world.

Research into banana genomics and biotech resulted in identification of over 5,300 genes, including those that address:

- Drought Tolerance
- RESISTANCES TO:
  - Fungi (Black and Yellow Sigatokas and Fusarium wilt)
  - Bacteria
  - Nematodes
  - Insects
Demand Planning and Operations
Standardization Exists Across the Industry of Order/Production Processes and the Two Key Product Options

**SMALL PLANTLETS** (more common for large farmers)

**LARGE PLANTLETS** (more common for small farmers)

**FARMER ORDER PLACED**

**MULTIPLICATION**

**ROOTING**

**GROWTH AT BIOFACTORY GREENHOUSE**

**ACCLIMITIZATION AT FARM**

**PLANTED IN FIELD**

- **Biofactory Lab**
- **Biofactory Greenhouse**
- **Farmer Greenhouse / Nursery**
- **Field**

Shipped to farmer

Shipped to farmer

Shipped to farmer
Biofactory Demand Planning

Orders typically taken 4-12 months in advance by a biofactory administrator via phone calls; this practice of advance orders makes demand planning more feasible for biofactories.

TC material is shipped directly to the individual farmers; there are no satellite nursery operations that serve as distributors or enablers between biofactories and farmers.

Shipping & transportation costs are the responsibility of the farmers; for longer distances, smaller plantlets are more ideal than large plantlets.

Depending on the biofactory, business may be entirely or majority from large farmers; however, small farmers also participate in TC material purchases.

Contracts are put in place for the great majority of orders. Typically 30-50% of the payment is due at time of order and the remainder is paid in installments after order is fulfilled.
The varietal preferences of bananas (Prata, Cavendish, Pacovan, BRS Princesa, Silk, etc.) are consistent year-over-year since most production is consumed domestically and taste preferences do not dramatically shift.

The banana market has been continuously growing but is dynamic (demand is cyclical with periods of boom/bust every 2-5 years).

Farmers strive to maximize production during market windows (Jan-Mar for Prata and Jun-Aug for Cavendish) when banana prices are highest; Timing for the first 2-3 harvest cycles is easier to manage; after a few years the harvest schedule is more sporadic and the best market windows are difficult to achieve.
Financial Sustainability
# Financial Sustainability

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>ESTIMATED FUNDING SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brazilian Agricultural Research Corporation</strong></td>
<td><strong>Brazilian Regional Seedling Distributors</strong></td>
</tr>
<tr>
<td>Embrapa</td>
<td>Campo / Biocell / Multiplanta / others</td>
</tr>
</tbody>
</table>

- **Royalties, 10%**
- **Federal Government, 90%**
- **Plantlet Sales, 100%**
- **Publicly Funded, 100%**
- **Other Sources, 30%**
- **Farmer Membership Fees, 70%**
- **Publicly Funded, 100%**
Estimated Revenues of two leading biofactories

<table>
<thead>
<tr>
<th># plantlets total</th>
<th>3,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large Plantlets</strong></td>
<td><strong>Medium Plantlets</strong></td>
</tr>
<tr>
<td>Price per plantlet ($R)</td>
<td>BRL 2.10</td>
</tr>
<tr>
<td>% plantlets</td>
<td>60%</td>
</tr>
<tr>
<td># plantlets</td>
<td>1,800,000</td>
</tr>
<tr>
<td>Revenue ($R)</td>
<td>BRL 3,780,000</td>
</tr>
<tr>
<td>Total Revenue ($R)</td>
<td>BRL 5,820,000</td>
</tr>
<tr>
<td>Total Revenue (USD)</td>
<td>$1,492,308</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># plantlets total</th>
<th>3,500,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large Plantlets</strong></td>
<td><strong>Medium Plantlets</strong></td>
</tr>
<tr>
<td>Price per plantlet ($R)</td>
<td>BRL 2.00</td>
</tr>
<tr>
<td>% plantlets</td>
<td>70%</td>
</tr>
<tr>
<td># plantlets</td>
<td>2,450,000</td>
</tr>
<tr>
<td>Revenue ($R)</td>
<td>BRL 4,900,000</td>
</tr>
<tr>
<td>Total Revenue ($R)</td>
<td>BRL 6,685,000</td>
</tr>
<tr>
<td>Total Revenue (USD)</td>
<td>$1,714,103</td>
</tr>
</tbody>
</table>

*Neither Multiplanta nor Biocell are multiplying farmers’ positively selected materials; all plantlets are produced from mother plants from clonal gardens*
Estimated revenue of TC materials sourced from clonal library vs. positively selected

Two partnerships of positively selected TC multiplication were discovered:

**1. Grupo Borborema**
- Borborema purchases ~150-300k plantlets from positively selected material annually at R$1.75/plantlet
- # Plantlets (total ~900k): 500,000 (clonal library) vs. 400,000 (positively selected)
- Cost per plantlet: BRL 1.40 (clonal library) vs. BRL 1.75 (positively selected)
- Revenue ($R): BRL 560,000 (clonal library) vs. BRL 875,000 (positively selected)
- % Revenue: 39% (clonal library) vs. 61% (positively selected)
- Total Revenue ($R): BRL 1,435,000
- Total Revenue (USD): $367,000

**2. Farm of Marcos Ribeiro**
- Marcos Ribeiro purchases ~100k plantlets from positively selected material annually at R$2.10/plantlet
- # Plantlets (total ~600k): 500,000 (clonal library) vs. 100,000 (positively selected)
- Cost per plantlet: BRL 1.70 (clonal library) vs. BRL 2.10 (positively selected)
- Revenue ($R): BRL 840,000 (clonal library) vs. BRL 210,000 (positively selected)
- % Revenue: 80% (clonal library) vs. 20% (positively selected)
- Total Revenue ($R): BRL 1,050,000
- Total Revenue (USD): $269,000

---

Assumes no additional positively selected TC multiplication partnerships exist; in reality small labs could be doing more.
Enabling Environment
# Regulatory Timeline (Ministry of Agriculture and Livestock – MAPA)

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
</table>
| 2003 | Law 10711 Establish norms of production across many crops, designates technical responsible supervisor nurseriesmen, supervising all phases. In order to open plantlet company, need to get permission with this law. Of the registered biofactories, all banana seedlings go through the registration (non-registered are other fruits) and annual / biannual audits by MAPA. Defines THREE classes of plantlets *(All three are common; non-certified does not represent poor quality)*  
1. **Non-certified without genetic origin**  
   Clones collected from field – Technical report required to prove it is virus free  
2. **Non certified with genetic origin**  
   Cones provided by Empraba  
3. **Certified**  
   Certified and documented according to standards of MAPA, free to be marketed to all Brazilian states and abroad. |
| 2005 | Normative Instruction No 24 Establish basic guidelines to be followed for the production, commercialization and use of planting material within the National territory, in order to assure identity and quality to any one interested in purchasing from companies in Brazil.  
More quality control for banana plantlets and prove mother plants have been tested for viruses (Banana Streak Virus & Cucumber Mosaic Virus)  
Happened because large farmers complained to MAPA, MAPA asked Embrapa to help implement feasible legislation to improve quality. Every 5 years it is put on private-public consultancy for alternating as needed. |
| 2010 | Normative Instruction No 46 Establish the Standards for the Production and Marketing of Seedlings and other types of planting material obtained through Plant Tissue Culture  
MAPA performs routine audits on biofactories. |
| 2012 | Normative Instruction No 22 |
As part of the regulated TC production process, biofactories are required to send samples (0.2% of their materials) to test two key viruses:

- Banana Streak Virus (BSV)
- Cucumber Mosaic Virus (CMV)

CIV/UFLA is one of the few virus indexing centers officially accredited by the Ministry of Agriculture to do this testing

- Test 50,000 samples per year
- Costs $R20/sample

The lab also plays an important role in shaping regulatory decisions with MAPA:

- Tests international banana plantlet materials:
  Ecuador is trying to enter the Brazilian plantlet market, but CIV/UFLA discovered virus in their materials and has worked with the Brazilian government to ensure regulations apply to imported materials

- Argues for all TC materials to be screened as positive selection becomes more mainstream:
  Small, Dutch-owned biofactories are trying to achieve an exception in the regulations for positively selected multiplied materials (side-stepping the virus testing requirement) but CIV/UFLA is working with MAPA to discourage this from passing due to the risk of virus dissemination
Projeto Famoso

Projeto Famoso is a government funded agricultural production region created in 1980s

There is a total of 9,800 hectares, 90% of which is banana (10% melon)

Originally intended for grain production but shifted to primarily banana production due to favorable agronomic conditions and demand

Government funded the installation of an irrigation system; now water management and ongoing maintenance done by farmer associations (via membership fees)

Canal irrigation systems provide essential water but also accelerates disease spread across the region

Now the region is almost fully privately owned and maintained
  • 972 farmers with 6 hectares or fewer
  • 188 farmers with 6-100 hectares

~70% of fruit produced in this region goes to Brasilia or Goiania
IFB has an ongoing initiative to bring biofactory/greenhouse to Projeto Famoso region

Helder Sampaio is a former Embrapa employee who now is working at IFB to support technical agronomy classes and farmer extension services

One ongoing initiative Helder is spearheading is to bring a local biofactory and/or greenhouse nursery to the Bom Jesus da Lapa region of Bahia

RATIONALE
Currently the “Projeto Famoso” region has many farmers producing bananas, but all the planting materials are being sourced from CAMPO, Multiplanta, Biocell, etc. (each hundreds or thousands of km from the production region)

OPERATIONAL STRUCTURE
Seeking a Public-Private Partnership between IFB and a private company (~R$500K still needed); Plan to retro-fit an existing facility for biofactory specifications

FACILITY
Considering a range of options:
• (Primary) Biofactory to produce banana TC plantlets
• (Secondary) Greenhouse / Nursery to support acclimation of small TC plantlets in-region before planting

ENABLEMENT FROM LARGE FARMERS
If the project of IFB would be successful, Nelson Jr & Filipe (large farmers in area) would be interested in supporting small farmers w/ their greenhouse/nursery capacities
Banana Farmer Associations

Four farmer associations represent ~60% of banana production in Brazil

- Jaranuba-Minas Gerais
- Corupa-Santa Catarina
- Vale do Rebeira-Sao Paulo
- Bom Jesus da Lapa-Bahia

(Banana da Bahia)
Bananas da Bahia – Farmer Association

28 associated farmers in Banana da Bahia

In addition to membership fees, farmers pay the association R$1 for each 22-kilo box of bananas sold

Almost 12 years old

Director – two roles: administrative and the other commercial – both voted in and receive salaries. Must be producers.

Primary focus of the association commercial:
- Have brokers who sell directly to distributors or retailers and guarantee a minimum price regardless of the time of year
- After harvest, association supports the sell of banana fruit
- Farmers paid a maximum of 45 days after delivery (independent of when it’s sold in store) with check issued weekly

Secondary focus is on supporting the purchase of TC materials; group of large farmers join to place a large order and achieve better price w/ biofactories, but do not rely on this as the only method (also purchase directly)

E N A B L I N G  E N V I R O N M E N T

Ervino Kogler
Director

Almost 12 years old
Embrapa Provides Agronomic & Economic Guidance to Brazilian Banana Producers

Embrapa’s series of 500 Questions, 500 Answers contains information generated from questions raised by the The Customer Service Department (SAC) of Embrapa Mandioca and Fruticultura, through letters, phone calls, fax and e-mail, researchers and technicians.

Source: Embrapa’s 500 Answers, 500 Questions
May 6-11, 2019: Tour Included Visits to Leaders Throughout the Value Chain

ACKNOWLEDGMENTS

- Research
- Biofactories
- Farmers / Farmer Associations / Academic Enablers

Locations included:
- Bom Jesus da Lapa-BA
- Cruz das Almas-BA
- Jaiba-MG
- Sete Lagoas-MG
- Andradas-MG
- Farm of Marcos Ribeiro

biofactories
research
farmers / farmer associations / academic enablers
Thank you for your time and support in the development of this Brazil Banana profile.

Case profile built off of leading firms and farmers in the industry; as relevant, differences will be described for smaller or more mainstream actors in the banana production system.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herminio Souza Rocha</td>
<td>Analyst on Business Technology Transfer</td>
<td>Embrapa Cassava &amp; Fruits</td>
</tr>
<tr>
<td>Edson Perito Amorim</td>
<td>Reseacher – Banana Breeding</td>
<td>Embrapa Cassava &amp; Fruits</td>
</tr>
<tr>
<td>Francisco Farraz Laranjeira</td>
<td>Assistant Director – R&amp;D</td>
<td>Embrapa Cassava &amp; Fruits</td>
</tr>
<tr>
<td>Mario Borborema</td>
<td>Director</td>
<td>Borborema Hortifuti</td>
</tr>
<tr>
<td>Edilson Paiva</td>
<td>Director</td>
<td>Biocell Clonagem e Diagnose Vegetal</td>
</tr>
<tr>
<td>Marcio de Assis</td>
<td>Partner &amp; Administrator</td>
<td>Multiplanta Tecnologia Vegetal</td>
</tr>
<tr>
<td>Ervino Kogler</td>
<td>President &amp; Director</td>
<td>Banana da Bahia</td>
</tr>
<tr>
<td>Nelson Estevao da Silva Jr.</td>
<td>Agronomic Engineer &amp; Farmer</td>
<td>Banana da Bahia</td>
</tr>
<tr>
<td>Helder Sampo</td>
<td>Professor</td>
<td>Instituto Federal Baiana</td>
</tr>
<tr>
<td>Antonia Figueira</td>
<td>Professor / Head of Indexing Center</td>
<td>Universidade Federal de Lavras</td>
</tr>
</tbody>
</table>
thank you

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