Challenges of the management of pest and diseases in organic banana production: a holistic and realistic point of view in export systems

L. de Lapeyre, Cirad, GECO
.... and many other contributors!
Focus of this communication

1. Banana production for exportation

.......... Reveals various constraints:

- Cultivation of Cavendish bananas only
- Susceptibility to crop enemies

- Cultivation generally in big farms or small farms in large areas
- Large epidemic processes

- Shipping 7-20 days
- Cooling at 13°C after packing
- Greenlife Acceptability of bananas
Focus of this communication

1. Banana production for exportation

.......... Reveals various constraints:

- Artificial ripening
- Greenlife Acceptability of bananas
- Commercialisation mainly in supermarkets

Economic constraints specific to banana markets
- Low prices in supermarkets
- Low tolerance for quality defects
- Short conservation in supermarkets and trade based on very specific pomologic traits

High yields
High quality standards
Focus of this communication

2. Control of pest and diseases in the frame of organic rules

- No synthetic pesticides
Focus of this communication

2. Control of pest and diseases in the frame of organic rules
Focus of this communication

2. Control of pest and diseases in the frame of organic rules

- Only some products allowed

1. Basic substances (from plants or animals, or mineral origin)
2. Low Risk active substances (ferric phosphate, Laminarin)
3. Micro-organisms
Focus of this communication

2. Control of pest and diseases in the frame of organic rules

- Only some products allowed

<table>
<thead>
<tr>
<th>Number and part of Annex (1)</th>
<th>CAS</th>
<th>Name</th>
<th>Specific conditions and limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>139A</td>
<td>131929-60-7</td>
<td>Spinosad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>131929-63-0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>225A</td>
<td>124-38-9</td>
<td>Carbon dioxide</td>
<td></td>
</tr>
<tr>
<td>227A</td>
<td>74-85-1</td>
<td>Ethylene</td>
<td>only on bananas and potatoes; however, it may also be used on citrus as part of a strategy for the prevention of fruit fly damage</td>
</tr>
<tr>
<td>230A</td>
<td>Li. 67701-09-1</td>
<td>Fatty acids</td>
<td>all uses authorised, except herbicide</td>
</tr>
<tr>
<td>231A</td>
<td>8008-59-9</td>
<td>Garlic extract (Allium sativum)</td>
<td></td>
</tr>
<tr>
<td>234A</td>
<td>CAS No not allocated CIPAC No 901</td>
<td>Hydrolysed proteins excluding gelatine</td>
<td></td>
</tr>
<tr>
<td>244A</td>
<td>298-14-6</td>
<td>Potassium hydrogen carbonate</td>
<td></td>
</tr>
<tr>
<td>249A</td>
<td>98999-15-6</td>
<td>Repellents by smell of animal or plant origin; sheep fat</td>
<td></td>
</tr>
<tr>
<td>255A and others</td>
<td>Pheromones and other semiochemicals</td>
<td>only in traps and dispensers</td>
<td></td>
</tr>
<tr>
<td>220A</td>
<td>1332-58-7</td>
<td>Aluminium silicate (kaolin)</td>
<td></td>
</tr>
<tr>
<td>236A</td>
<td>61790-53-2</td>
<td>Kieselguhr (diatomaceous earth)</td>
<td></td>
</tr>
</tbody>
</table>

| 247A                         | 14808-60-7, 7637-86-9 | Quartz sand |                                |
| 343A                         | 11141-17-6, 8459-25-5 | Azadirachtin (Mangoxa extract) extracted from Neem tree seeds (Azadirachta indica) |                                |
| 240A                         | 8000-29-1     | Citronella oil  | all uses authorised, except herbicide |
| 241A                         | 84961-50-2    | Clove oil       | all uses authorised, except herbicide |
| 242A                         | 8002-13-9     | Rape seed oil   | all uses authorised, except herbicide |
| 243A                         | 8008-79-5     | Spearmint oil   | all uses authorised, except herbicide |
| 56A                          | 8028-48-6, 5989-27-5 | Orange oil | all uses authorised, except herbicide |
| 228A                         | 68647-73-4    | Tea tree oil    | all uses authorised, except herbicide |
| 246A                         | 8003-34-7     | Pyrethrins extracted from plants |                                |
| 292A                         | 7704-34-9     | Sulphur         |                                |
| 294A 295A                    | 64742-46-7, 7263-8-60, 97862-82-5, 8042-47-5 | Paraflin oils |                                |

Pesticide use is generally very important in most tropical humid areas where banana is produced.
How challenging is it?

Kg of active ingredient used in one year in a representative conventional farm in humid tropics

% of quantity of active ingredient used in one year in a representative conventional farm in humid tropics

✓ Fungicide use is very important
Which levers?

- Cultivar
- Crop rotations
- Intercropping
- Prophyllaxy
- Barriers
- Pruning
- Plant nutrition
- Harvest management
- Physical methods
- ……

Biota against biota
- Microorganisms
- Macroorganisms
- Plants

Natural substances (should be approved)
- Plant extracts
- Mineral origin
- Pheromones

Cultural Practices
Integrated strategy
Location
Biocontrol

Dry tropics
Focus on the most specific problems for OA (replacement of pesticides)

- **Weeds / competition**
- **Bulb:** Black weevil
- **Roots:** Nématodes (Radopholus similis)
- **Leaves:** Black Leaf Streak Disease
- **Fruits:** Anthracnose, Crown rot

Other conference

Generaly minor problems in dry tropics: efficient solutions exist (Fallow, trapping)

Excluded:
* Telluric fungi (*Fusarium* wilt)
* Viral diseases
* Bacterial diseases
Example 1.
Black Leaf Streak Disease control in organic farms
Direct reduction of photosynthesis

Dammages = important defoliation

Yield loss

Indirect Reduction of greenlife

Unexported bunches

Beginning of cycle

Crop cycle

Flowering

Harvest

Shipping

Early ripening

Reduction of yield in next cycle
Black Leaf Streak Disease

1. Location of organic farms in dry areas is the most important lever used by farmers

<table>
<thead>
<tr>
<th>Places dedicated to organic banana production</th>
<th>Surfaces</th>
<th>Annual rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peru (Piura)</td>
<td>9500 ha</td>
<td>100 mm</td>
</tr>
<tr>
<td>Ecuador (Machala)</td>
<td>20000 ha</td>
<td>500 mm</td>
</tr>
<tr>
<td><strong>Dominican Republic</strong> (Mao-Montecristi, Azua)</td>
<td><strong>18000 ha</strong></td>
<td><strong>500-1000 mm</strong></td>
</tr>
<tr>
<td>Ghana</td>
<td>600 ha</td>
<td>700-1000 mm</td>
</tr>
<tr>
<td>Colombia (La Guajira)</td>
<td>3000 ha</td>
<td>700-1000 mm</td>
</tr>
<tr>
<td>Mexico (Colima)</td>
<td>4000 ha</td>
<td>700-1000 mm</td>
</tr>
</tbody>
</table>

Annual rainfall < 1000 mm mainly to maintain BLSD at low level

Water is transported to fields by large canals

Water is pumped or flooded in plots
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

Lots of advertising !
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

Dry periods might be a mirage of efficiency!
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

✓ Many products have been registered in all organic banana growing countries

✓ Efficiency is rarely evaluated in good conditions : low disease level, no untreated control, products are mixed with mineral oil

✓ Solid evaluation has been made in different contexts : Dominican Republic, Ivory Coast
  • Experimental plots with 3-4 blocks
  • Untreated control in each block
  • Reference treatment in each block : mineral oil at 12-15l/ha
  • Broad range of disease descriptors : SED, YLSt, YLS, Number of lesions, Functionnal leaves at flowering
  • Long period : several weekly applications (at least 10)
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

Stage of Evolution

Qualitative evaluation of disease on young leaves
2. The quest for alternative fungicides .... or a miracle

Estimate of Incubation period

YLSt = 3

Black Leaf Streak Disease

Age of leaves

Sporulation

Incubation

conidia

F2
F4
F6
F8
F3
F5
F7
F9

F1

YLSt
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

YLS = 9

Estimate of disease cycle duration
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

Number of lesions (leaves 3 to 10)

Quantitative evaluation of infections
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

<table>
<thead>
<tr>
<th>Untreated control</th>
<th>Defense elicitor</th>
<th>Tea Tree</th>
<th>Bacillus pumilis</th>
<th>Potassium bicarbonate</th>
<th>Bacillus subtilis</th>
<th>Plant extract (thymol, eugenol)</th>
<th>Mineral oil 15 l/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>SED</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>YLSt</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>YLS</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>Number of lesions</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b (-90%)</td>
</tr>
<tr>
<td>Green leaves</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
</tbody>
</table>

❖ Most approved biofungicides are ineffective: no difference with untreated control
❖ Mineral oil remains the best protection
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

<table>
<thead>
<tr>
<th></th>
<th>Untreated control</th>
<th>Eucalyptus extract</th>
<th>Eucalyptus extract + oil</th>
<th>Mineral oil</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SED</strong></td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td><strong>YLSt</strong></td>
<td>a</td>
<td>a</td>
<td>c</td>
<td>b</td>
</tr>
<tr>
<td><strong>YLS</strong></td>
<td>a</td>
<td>a</td>
<td>c</td>
<td>b</td>
</tr>
<tr>
<td><strong>Number of lesions</strong></td>
<td>a</td>
<td>b</td>
<td>d</td>
<td>c</td>
</tr>
<tr>
<td><strong>Green leaves</strong></td>
<td>a</td>
<td>b</td>
<td>d</td>
<td>c</td>
</tr>
</tbody>
</table>

❖ Some plant extracts mixed in oil might improve biological efficiency vs reference
❖ More exploration is needed
❖ Organic certification is needed (country, UE, EPA, certificaying bodies)
Black Leaf Streak Disease

2. The quest for alternative fungicides .... or a miracle

✓ Mineral oil is generally a good lever for BLSD control but depends on precipitations and irrigation methods.
✓ Probably not sufficient in large plantations when rainfall > 1000 mm

<table>
<thead>
<tr>
<th>Dominican Republic trial</th>
<th>Oil/Forecast year 1</th>
<th>Oil/Forecast year 2</th>
<th>Oil/Forecast year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SED</td>
<td>33</td>
<td>316</td>
<td>841</td>
</tr>
<tr>
<td>YLSt</td>
<td>8,1</td>
<td>6,0</td>
<td>4,2</td>
</tr>
<tr>
<td>YLS</td>
<td>11,3</td>
<td>10,3</td>
<td>7,3</td>
</tr>
<tr>
<td>Leaves at harvest</td>
<td>8,4</td>
<td>8,1</td>
<td>4,2</td>
</tr>
<tr>
<td>Number of treatments</td>
<td>1</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Rainfall</td>
<td>352</td>
<td>1145</td>
<td>1602</td>
</tr>
</tbody>
</table>
Black Leaf Streak Disease

3. Deleafing a multifunctional lever underestimated

A very efficient **prophylactic tool** largely performed in most banana farms!

- Ascospores are very abundant in unmanaged plots
  
  ![Graph showing ascospore abundance](from Rieux et al, Heredity: 2013; 110)

- Necrotic leaves might produce large amounts of ascospores for more than 150 days (Gauhl, 1994)

- Deleafing of necrotic leaves drastically reduces inoculum abundance
  
  ![Graph showing lesion reduction](from Poeydebat et al, Phytopathology: 2018; 108)
Black Leaf Streak Disease

3. Deleafing a multifunctional lever underestimated

A very efficient and **poorly recognized tool** to mitigate BLSD on greenlife

- Deleafing one month before harvest has a strong effect on GL (Yellow Sigatoka)
- When regular deleafing of necrotic spots is performed in highly infested spots, GL is not much affected (BLSD)
Black Leaf Streak Disease

3. Deleafing a multifunctional lever underestimated

A very efficient and **poorly recognized tool** to mitigate BLSD on greenlife

Intensity:
- Quantity of necrotic stages
- Duration of necrotic presence

Leaf signal

Elimination of necrotic leaves (post-flowering)
3. Deleafing a multifunctional lever underestimated

A very efficient and **poorly recognized tool** to mitigate BLSD on greenlife

Comparison of two strategies in Humid climate in Martinique through 3 cycle crops

- **Reference** = chemical strategy
- **Prototype** = strategy only based on regular weekly deleafing of necrotic stages

*From Guillerm et al., 2016*
Black Leaf Streak Disease

3. Deleafing a multifunctional lever underestimated

A very efficient and **poorly recognized tool** to mitigate BLSD on greenlife

Comparison of two strategies in Humid climate in Martinique through 3 cycle crops

- Reference = chemical strategy
- Prototype = strategy only based on regular weekly deleafing of necrotic stages

From Guillermet et al., 2016

Moderate reduction of bunch weight

Moderate reduction of greenlife: no ripe
Black Leaf Streak Disease

4. Complementary levers

❖ Irrigation system
Limit wet environment in field

❖ Harvest stage according to physiological age
Preserve greenlife even in case of high infestation

❖ Bunch reduction
Compensate leaf surface reduction

From Ecochard, 2020
## Black Leaf Streak Disease

5. Synthesis of levers for BLSD control in organic farms

<table>
<thead>
<tr>
<th>Location</th>
<th>Biological control</th>
<th>Natural substances</th>
<th>Agricultural practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry areas ++++++</td>
<td>Microorganisms +/-</td>
<td>Mineral oil +++</td>
<td>Necrotic stages removal +++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant extracts +</td>
<td>Harvest stage ++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit pruning +</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irrigation +</td>
<td></td>
</tr>
</tbody>
</table>

All levers must be combined for acceptable control!
Black Leaf Streak Disease

6. Other levers that need to be further explored

- Resistant varieties

Resistant varieties are available but:
- Crop management is very different to Cavendish and production costs higher or yield lower (Dorel et al, 2016)
- Fruits might suffer physiological defects
- Fruit are not adapted to the transport and the ripening process
- Fruits are not adapted to trade in supermarkets
Black Leaf Streak Disease

6. Other levers that need to be further explored

- Plot diversification with trees (agroforestry)
- **Barriers to dispersion**
  - longer distance between hosts
- **Increase of incubation time**
  - microclimate
  - phyllosphera microbiome
- **Reduction of spore abundance**
  - spore interception
  - less inoculum sources

From Poeydebat et al., Phytopathology, 2018; 108
6. Other levers that need to be further explored

- Plant nutrition

Probably a trade off between plant growth and BLSD development: an optimum should be found.
Example 2.
Postharvest diseases control in organic farms

Crown rot

Anthracnose
Various postharvest diseases

- **Field**
  - Fungal complex

- **Packing station**
  - Wounds
  - No wounds

- **Shipping**
  - Break of quiescence
  - Wound anthracnose
  - 10-20 days
  - ethylene

- **Commercialisation**
  - Quiescent anthracnose
  - ethylene
  - Crown rot

- **Anthracnose**
  - Colletotrichum musae

- **Crown rot**

Quiescence
# Postharvest diseases control in organic farms

- **Synthesis of effective levers**

<table>
<thead>
<tr>
<th>Location</th>
<th>Biological control</th>
<th>Natural substances</th>
<th>Agricultural practices (pre-harvest)</th>
<th>Agricultural practices (post-harvest)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ideal place:</strong></td>
<td>Should be better explored Nexy (yeast) +/-</td>
<td>Should be better explored * citric acid +</td>
<td>Prophyllaxy: * Floral remnants + bracts removal * Bunch bagging Reduce fruit infection with C. musae ++++</td>
<td>Prophyllaxy: * Bunch washing * Packing station cleaning * Water quality Reduce crown contamination +++</td>
</tr>
<tr>
<td>* dry area and low temperatures (highland) Reduce fruit susceptibility ++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant extracts +/-</td>
<td>Harvest stage Reduce fruit susceptibility ++</td>
<td>Fruit conservation * Cooling * Modified or controlled atmosphere +++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fruit pruning Reduce fruit susceptibility to CR when NLH is low +</td>
<td></td>
</tr>
</tbody>
</table>
Postharvest diseases control

Effect of removal of inoculum sources and sleeving et on Colletotrichum musae fruit contamination scored at harvest

(From de Lapeyre et al., Plant Pathology, 2000)

![Bar chart showing the effect of different treatments on average anthracnose lesions on fruit.](chart.png)

- No control
- Removal of inoculum sources
- Sleeving
- Removal of inoculum sources + Sleeving
Conclusion.....

❖ No unique solution (silver bullet) for pest and disease control but an integrated more complex combination of levers

❖ Organic banana extension to rainy areas relies on new varieties resistant to BLSD

❖ Future of organic farming is undoubtdely towards a diversification of farms and intercropping with trees
Thank you for your attention