Findings and advances on *Ganoderma* in oil palm.

Tristan Durand-Gasselin, Nicolas Turnbull, Hubert de Franqueville, Frédéric Breton, Indra Syahputra and Benoit Cochard.
Ganoderma is a major disease to oil palm

It causes considerable losses in Asia and in Africa (Up to 80%)
Field symptoms

Thailand

Indonesia

Cameroon

PT SOCFIN INDONESIA
(SOCFINDO)
Carpophorus
Basal Stem Rot
Ganoderma?
About Ganoderma

Ganoderma species may cause diseases on:

- Oak
- Maple
- Sycamore
- Areca (Betelnut)
- Acacia
- ..... and oil palm

Ganoderma boninense on Bactris
About *Ganoderma*

- *Ganodermataceae* are *basidiomycota* fungi.
- Taxonomy is very confused: it is a difficult genera among the polypore.
- More than 400 names... but probably only 100 to 150 species. May be only 80....
- Colour, shiny or dull, morphology, Geography, spores/basidiospores, hyphal elements... leads to a lot of confusions.
About *Ganoderma*

- Today we have different molecular tools that has their own utility. Among them:
  - **ITS** (Internal Transcribed Spacer from ribosome DNA) is very convenient to characterize species and to construct phylogenetic relationship. (Supraspecific, specific, subspecific, less efficient for population-level relationships).
  - **SSR** (Simple Sequence Repeats (microsatellites)) are useful to study the genetic diversity within species and to identify races.
Phylogenetic of *Ganoderma*

In Asia, *G. boninense* is generally the one associated to oil palm.

From J-M. Moncalvo

Frequently related to palms

**G. zonatum**  
**G. boninense**

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*From J-M. Moncalvo*
Ganoderma: diversity

372 isolates Asia SE (Thailand + Penninsular Malaisia + Indonesia Sumatera)

32 isolates from Cameroun

34 isolates from Bornéo

Is the work done in Sumatra valid for Borneo or Africa?

From:
J. S. Tan
F. Breton
L. Camus
M. Mercière

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Biology of *Ganoderma*

- *Ganoderma*, as most basidiomycota, have a monocaryotic (n) and a dicaryotic phase (2n).
- The dicaryotic phase result from the fusion 2 monocaryotic mycelium as long as they are of mating compatible type.

⇒ Only the dicaryotic mycelia is pathogenic
What did we learn from the field?
Ganoderma & Previous crop

⇒ Ganoderma infection will increase with 2nd generation of oil palm and further

From Singh, 1991
Dispersion of *Ganoderma*

- Palm to palm through roots? ⇒ Yes
- Dispersion through spores? ⇒ Very likely yes also.

Some confirmation:

- Role of roots has been confirm since long (Turner/Arifin)
- Bait palms are infected by the same strain (Flood)
- Huge diversity within a field (Sanderson/Pilotti)
Dispersion of *Ganoderma* (Cont..)

One palm and different strain:

⇒ We have to keep in mind that situations are diverse.
Bait Palms

Infected adult palm ⇒ Infection of bait palms is very fast (< 2 years)

⇒ It has been found that the strains were identical (J. Flood)

Bait Palms

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## Bait Palms/Removing the source

The table below shows the status of the bole, depth of the bole, and percentage of bait seedling infected at different depths:

<table>
<thead>
<tr>
<th>Status of the bole</th>
<th>Depth of the bole</th>
<th>% bait seedling infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infected (BSR)</td>
<td>0</td>
<td>75 %</td>
</tr>
<tr>
<td>Infected (BSR)</td>
<td>20 cm</td>
<td>58 %</td>
</tr>
<tr>
<td>Infected (BSR)</td>
<td>40 cm</td>
<td>28 %</td>
</tr>
<tr>
<td>Infected (BSR)</td>
<td>60 cm</td>
<td>21 %</td>
</tr>
<tr>
<td>Infected (BSR)</td>
<td>80 cm</td>
<td>0 %</td>
</tr>
<tr>
<td>Infected (BSR)</td>
<td>100 cm</td>
<td>0 %</td>
</tr>
<tr>
<td>Control (Healthy)</td>
<td>60</td>
<td>0 %</td>
</tr>
</tbody>
</table>

*From Flood et al. 2000*

Removing the source

⇒ Replanting to be done far from the sources
Replanting at the same density

Replanting between old palms is a good compromise
Changing the initial density

Old trees

New trees (160/ha)

Increase the risk of BSR
Akbar was the first to report, in 1971, the high susceptibility to BSR of pure Deli planted in North Sumatra as compared to Deli x Yangambi.

Mata Pao: Plantations 1955 and 1958
Tanah Gambus: Plantations 1957
Observations: 1970

Source: from Akbar et al. 1971
Genetic background
Genetic back ground

Mata Pao Estate (Indonesia): 17 years old plantation

Commercial material normal
Other clones
Clone SOC 001

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PalmElit

XVIII Conferencia Internacional sobre PALMA DE ACEITE
18th International Oil Palm Conference
IPM of *Ganoderma*

Breeding is now a key component provided good cultural practices are followed.

- **GENETIC (BREEDING)**
  - Field screening trials
  - Nursery screening trials

- **CHEMICAL CONTROL**
  - Screening fungicides
  - Application method

- **BIOLOGICAL CONTROL**
  - *Trichoderma* spp.
  - Endophytic Bacteria

- **CULTURAL PRACTICES**
  - Land Preparation
  - Sanitation
  - Felling...

**Development of an Integrated Pest Management (IPM)**
## CULTURAL PRACTICES

<table>
<thead>
<tr>
<th>Practice</th>
<th>Effect / Usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitation before replanting:</td>
<td></td>
</tr>
<tr>
<td>• Bole removing</td>
<td>Yes</td>
</tr>
<tr>
<td>• Shipping</td>
<td></td>
</tr>
<tr>
<td>Distance to previous palm</td>
<td>Yes</td>
</tr>
<tr>
<td>Sanitation during the generation</td>
<td>Yes probably</td>
</tr>
<tr>
<td>Removing fruiting bodies</td>
<td>Probably no</td>
</tr>
<tr>
<td>Trenches</td>
<td>No</td>
</tr>
<tr>
<td>Mounding</td>
<td>Yes for a few month</td>
</tr>
</tbody>
</table>
Breeding for *Ganoderma* resistance

Genetic resistance to *Ganoderma* in the field was reported ... in 1971 (Akbar..) in 2001 (de Franqueville..)
Breeding for *Ganoderma* resistance

1974–1998

Incidence of *Ganoderma*

Parental Material.

⇒ The Deli origin is a source of high susceptibility
BB CL 2
Planting 1986
2\textsuperscript{nd} generation

1992
BB CL 2
Planting 1986
2nd generation

1993
BB CL 2
Planting 1986
2\textsuperscript{nd} generation
1994
BB CL 2
Planting 1986
2nd generation
1995
BB CL 2
Planting 1986
2nd generation
1996

Healthy
Ganoderma symptoms
Oryctes
Replacements
Not in trial
BB CL 2
Planting 1986
2nd generation

1997
BB CL 2
Planting 1986
2nd generation

1998
BB CL 2
Planting 1986
2nd generation

Healthy
Ganoderma symptoms
Oryctes
Replacements
Not in trial

1999
PlanRng 1986
2nd generation

2000

BB CL 2
Planting 1986
2nd generation

Healthy
Ganoderma symptoms
Oryctes
Replacements
Not in trial
BB CL 2
Planting 1986
2\textsuperscript{nd} generation

2002
BB CL 2
Planting 1986
2nd generation

2003
BB CL 2
Planting 1986
2<sup>nd</sup> generation

2006
Overall infection levels will depend on **planting material** but also on **land preparation** and **agricultural practices**.
Specific Resistance (monogenic resistance) = complete resistance to some specific isolates/races

Non-specific Resistance (multigene resistance) = partial resistance effective against all isolates/races of the pathogen.

As a consequence the planters must not expect « Zero Disease »
The International Seed Federation encourage seed producer to define following wording:

Immunity, resistance, tolerance, susceptibility...

The ISF encourage to classify varieties in three levels:
highly resistant or intermediate resistant or non resistant. [http://www.euroseeds.org/publications/esa_12.0605.pdf/view](http://www.euroseeds.org/publications/esa_12.0605.pdf/view)

Our strategy aims at selecting for multiple defense genes involved in (partial) resistance. This selection will push toward providing sustainable resistance.
Early screening test

A burden!

- 100 crosses x 100 plants / test
- 10 tests / year / location

→ 120,000 palms / year
index

- Base 100: Trial mean

Susceptibility

Resistance

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Early screening test

**Repeatability:**

To what extend is the test consistent?

<table>
<thead>
<tr>
<th>Trial</th>
<th>Susceptible cross</th>
<th>Resistant cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>143</td>
<td>89</td>
</tr>
<tr>
<td>Test 2</td>
<td>98</td>
<td>73</td>
</tr>
<tr>
<td>Test 3</td>
<td>101</td>
<td>75</td>
</tr>
<tr>
<td>Test 4</td>
<td>102</td>
<td>72</td>
</tr>
<tr>
<td>Test 5</td>
<td>102</td>
<td>77</td>
</tr>
<tr>
<td>Test 6</td>
<td>112</td>
<td>78</td>
</tr>
<tr>
<td>Test 7</td>
<td>143</td>
<td>82</td>
</tr>
<tr>
<td>Test 8</td>
<td>144</td>
<td>85</td>
</tr>
<tr>
<td>Test 9</td>
<td>152</td>
<td>89</td>
</tr>
<tr>
<td>Test 10</td>
<td>121</td>
<td>89</td>
</tr>
</tbody>
</table>

**Yes:** but needs repetitions....
Early screening test

**Interaction:** Are resistances to one isolate of *Ganoderma* valid for all isolates?

<table>
<thead>
<tr>
<th>Isolate (aggressivity)</th>
<th>Progenies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>V (++)</td>
<td>2</td>
</tr>
<tr>
<td>W (+++</td>
<td>2</td>
</tr>
<tr>
<td>X (++)</td>
<td>1</td>
</tr>
<tr>
<td>Y (++)</td>
<td>2</td>
</tr>
<tr>
<td>Z (-)</td>
<td>1</td>
</tr>
</tbody>
</table>

Yes: ranking is very much the same....
Early screening test

Can resistance be explained by an additive model?

<table>
<thead>
<tr>
<th>Gano Index</th>
<th>Origin</th>
<th>Yangambi 1 &amp; 1'</th>
<th>Yangambi 2</th>
<th>La Mé 1</th>
<th>La Mé 2</th>
<th>La Mé 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deli 1</td>
<td>125</td>
<td>117</td>
<td>97</td>
<td>115</td>
<td>118</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Deli 2</td>
<td>107</td>
<td>107</td>
<td>90</td>
<td>122</td>
<td>86</td>
<td>Intermediate to resistant</td>
</tr>
<tr>
<td>Deli 3</td>
<td>105</td>
<td>129</td>
<td>95</td>
<td>---</td>
<td>107</td>
<td>Susceptible to intermediate</td>
</tr>
<tr>
<td>Deli 4</td>
<td>139</td>
<td>122</td>
<td>86</td>
<td>102</td>
<td>103</td>
<td>Susceptible to intermediate</td>
</tr>
<tr>
<td>Deli 5</td>
<td>109</td>
<td>114</td>
<td>82</td>
<td>99</td>
<td>88</td>
<td>Intermediate resistant</td>
</tr>
</tbody>
</table>

Yes, transmission is additive
As Early screening test is:
1. Repeatable
2. Does not show interaction isolate / planting material.
3. Additivity is the main effect

This enables us to design tests with reference parents (testors):

Pisifera 1
Pisifera 2
Pisifera 3
Pisifera 4

\( \times \) Same Pisifera \( \Rightarrow \) Pisifera and are compared red
GeneRc structure

Testors x

Palm 1
Palm 2
Palm 3
Palm 
Palm 
......

Family 1

Origin 1

Family 2

A Group,
(Deli, Angola,..

Family x

Origin ......

Family y

B Group
(La Mé, Yangambi, Nigeria,...

Family .....
Prenursery test
Variability within A Group

Estimated Index for different A group origins

One origin
14 families

Index

Estimated Index for Deli I origin (14 families)

Each family is represented by a significant number of crosses (vs testors)
Link with the field
## Field test

Field trial Gano 1: % Infection at 10 years old

<table>
<thead>
<tr>
<th>Origins</th>
<th>Deli x La Mé</th>
<th>La Mé A</th>
<th>Yambi IRHO A</th>
<th>La Mé B</th>
<th>Nigeria A</th>
<th>Nigeria B</th>
<th>Yangambi Socfin A</th>
</tr>
</thead>
<tbody>
<tr>
<td>D Dabou A</td>
<td></td>
<td>18</td>
<td>10,4</td>
<td></td>
<td>8</td>
<td>4</td>
<td>Intermediate resistant</td>
</tr>
<tr>
<td>D Dabou B</td>
<td></td>
<td>0</td>
<td>16,7</td>
<td></td>
<td></td>
<td>10</td>
<td>Intermediate resistant</td>
</tr>
<tr>
<td>D Dabou C</td>
<td>14,6</td>
<td>7,3</td>
<td>9,1</td>
<td>8,3</td>
<td>12,1</td>
<td>10,2</td>
<td>Intermediate resistant</td>
</tr>
<tr>
<td>D Dabou D</td>
<td>15,3</td>
<td>7,4</td>
<td>6,3</td>
<td>3,4</td>
<td>4,8</td>
<td>9,1</td>
<td>Resistant</td>
</tr>
<tr>
<td>D Dabou E</td>
<td>31,3</td>
<td>8,3</td>
<td>12,9</td>
<td>13,2</td>
<td>16,3</td>
<td>22,9</td>
<td>Susceptible</td>
</tr>
<tr>
<td>D Nifor A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17,6</td>
<td>Susceptible</td>
</tr>
<tr>
<td>D Nifor B</td>
<td>22</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>13</td>
<td>16</td>
<td>Intermediate resistant</td>
</tr>
<tr>
<td>D Socfin A</td>
<td>16,7</td>
<td>2,1</td>
<td>0</td>
<td></td>
<td>12,5</td>
<td>13,4</td>
<td>Resistant</td>
</tr>
<tr>
<td>DSocfin B</td>
<td>6,2</td>
<td>14,6</td>
<td>15</td>
<td></td>
<td></td>
<td>12,5</td>
<td>Intermediate resistant</td>
</tr>
</tbody>
</table>

- **Susceptible**
- **Resistant**
- **Intermediate resistant**

Resistant x Resistant genitors → Resistant progeny (7,4%)
Susceptible x Susceptible genitors → Susceptible progeny (22,9%)
Susceptible x Resistant genitors → intermediate progeny (8,3%-13,4%)
Selection of parents for \textit{Ganoderma} resistant seeds

**Parental garden or seed garden**
- Bangun Bandar Seed Garden: 211 ha
- Aek Kwasan II Seed garden: 160 ha
- Aek Kwasan II Parental Garden: 160 ha

**Progeny trials**
- Bangun Bandar: 95 ha (12 trials)
- Aek Loba Timur Project: 325 ha (28 trials)
- Aek Kwasan II Project: 392 ha (27 trials)

**Specific ganoderma trials**
- Bangun Bandar: 259 ha (8 trials)
- Mata Pao: 107 ha (5 trials)
- Tanah Gambus: 126 ha (5 trials)

(Parially available)

**Early screening test**
- 2,940 DP crosses tested
- 2,594 test crosses tested

To select a parent: \textbf{3 green lights}, and no warning...
Selection of Deli

5 Deli origins available

New / Waiting for field validation
All pisifera have been selected within the best origin (La Mé A)
### Seed production

#### 1 selected la Mé origin

#### 5 selected Deli origins

<table>
<thead>
<tr>
<th>Category</th>
<th>S **34</th>
<th>S <strong>35</strong></th>
<th>S <strong>50</strong></th>
<th>S <strong>79</strong></th>
<th>S <strong>91</strong></th>
<th>S <strong>94</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1'</td>
<td>P2'</td>
<td>P3'</td>
<td>P4'</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

D x P
Gano Resistant seeds

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Use of the genetic variability

- All parents for general seed prod
- Selected parents for MTG seed prod
- MT Gano seeds

Ganoderma levels

More resistant

More susceptible

mA'

mB'

Group A

Group B

D x P Gano Resit
Perspectives

1. Seeds will be improved continuously from intermediate resistance towards high resistances.

2. Development of molecular markers to help breeders (QTLs, QTAs,....)

3. Development of Clones

4. Better understanding of the interaction Ganoderma / Oil Palm
Conclusion

- Ganoderma exist in all continent
- Some **agricultural practices** are efficient to control it
- Evidence of genetic resistance in the field.
- Development of an early screening test.
- Additive inheritance.
- Intensive screening of parents A & B groups
- **Ganoderma partially resistant seeds** are available

⇒ An added value for planters
Gracias
Mauricio
Merci
<table>
<thead>
<tr>
<th>Socfindo (1970)</th>
<th>Block</th>
<th>Planting year</th>
<th>Type of material</th>
<th>% BSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mata Pao</td>
<td>2</td>
<td>1958</td>
<td>Deli x Deli</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1955</td>
<td>Deli x Deli</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1955</td>
<td>Deli x Deli</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1955</td>
<td>Deli x Deli</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>1958</td>
<td>Deli x Yangambi</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>1958</td>
<td>Deli x Yangambi</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanah Gambus</td>
<td>32</td>
<td>1957</td>
<td>Deli x Deli</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>1957</td>
<td>Deli x Deli</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>47</td>
<td>1957</td>
<td>Deli x Yangambi</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>53</td>
<td>1957</td>
<td>Deli x Yangambi</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Akbar et al. 1971

Akbar was the first to report, in 1971, the high susceptibility to BSR of pure Deli.
Simulation : added value /ha
## Simulation: added value /ha

### Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price</td>
<td>800 USD</td>
</tr>
<tr>
<td>Actualisation rate (for NAV)</td>
<td>0,05</td>
</tr>
<tr>
<td>Compensation by neighbor</td>
<td>0,5</td>
</tr>
<tr>
<td>End of compensation</td>
<td>0,7</td>
</tr>
</tbody>
</table>

### Total oil for one cycle 25 years

<table>
<thead>
<tr>
<th></th>
<th>MT Gano</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumul Palm oil</td>
<td>183 t</td>
<td>146 t</td>
</tr>
<tr>
<td>Net Value /ha</td>
<td>140 878 USD</td>
<td>116 829 USD</td>
</tr>
<tr>
<td>NAV /ha</td>
<td>73 574 USD</td>
<td>65 071 USD</td>
</tr>
</tbody>
</table>

### Additional Net Value /ha

- Gano T: 12 416 USD
- Commercial: 3 824 USD

### Per palm

- Gano T vs Comm: 120 USD
- NAV: 43 USD