Ganoderma and Basal stem rot:

From Pathogen knowledge to field solution

Maxime MERCIERE

CAMSEEDS
Responsible tropical agriculture

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Plan

I. The fungus: *Ganoderma* species complex
   - History and Biology
   - Understanding its demographical history to predict its futur

II. Host interaction: The basal stem rot
   - Host symptoms description
   - Historical impact on oil palm plantation
   - Control strategies developed until now and their efficiency

III. Conclusion

I. The fungus: *Ganoderma* species complex

G. *lipsiense*

G. lucidum

Fungal history and biology

- *Ganoderma* is part of Ganodermatacae family
- The Genus *Ganoderma* was firstly described by Krasten *(1881)*, then many classification were attempt but inconclusive because of the lack of reliable morphological characteristics, the overabundance of synonyms and the widespread misuse of names *(Ryvarden, 1985)*
- *Ganoderma* species are grouping more than 200 described species around the world (www.indexfungorum.org, 2019)
- *Ganoderma* species are soil born fungus mostly involved into decaying dead wood in forest (stumps, fallen trunks, rotten roots…)
- Among the 200 species described, more than 20 species were described as pathogenic on diverse species of plant: maples, oaks, honey locusts, elms, conifers, rubber… and palms!

- *Ganoderma* species pathogen to palm are spread all over tropical and sub-tropical region (South and North America, Africa, India and Asia)

- About 3 species described as pathogenic on oil palm in S-E ASIA (Idris AS et al., 2000) and about 7 species in Africa (Tonjock RK et al., 2015)

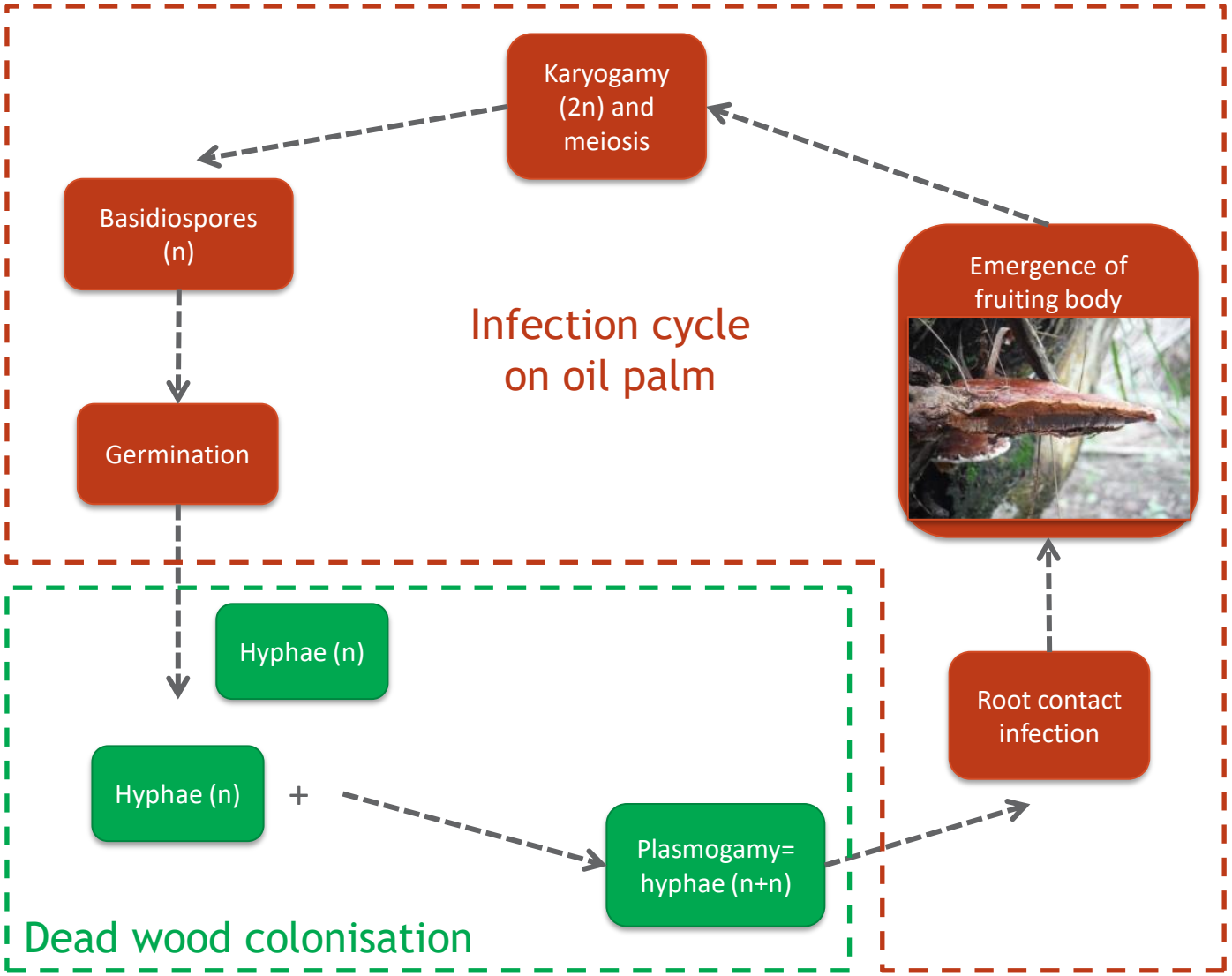
- Complex sexual reproduction involving a multi-allelic and bi-factorial sexual reproduction system. (Pilotti et al. 2002)

G. zonatum

G. applanatum

G. boninense

Ganoderma spp. life cycle



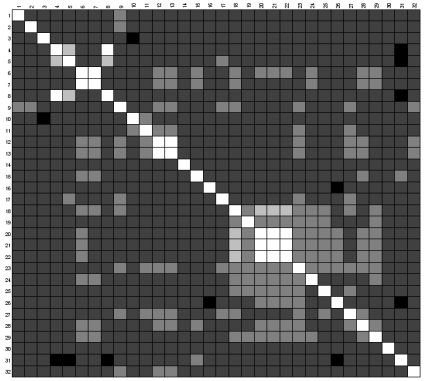
Clonal propagation vs reproduction

2 main theories for Ganoderma dispersal:

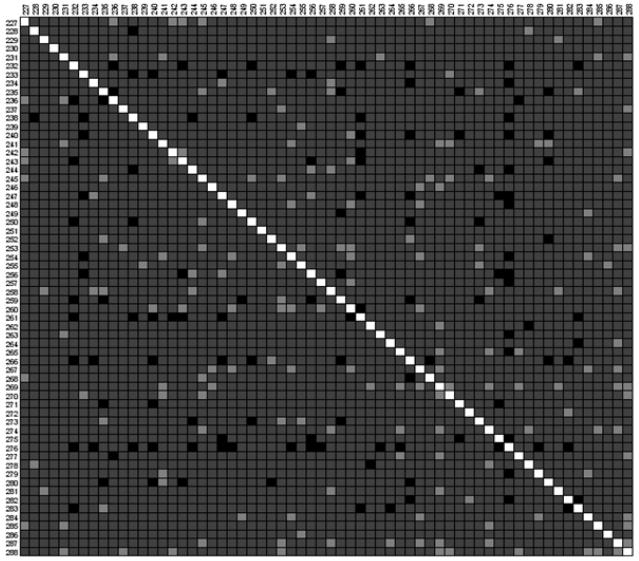
- Clonal: from debris of old infected trees buried or from root to root contact with an infected neighbor tree
- Reproduction: from basidiospore production and dispersal

Clonal propagation vs reproduction

Borneo (East Sabah)



Sumatra (Mata Pau)



- "The distribution of mating type alleles of G. boninense assigned in this study suggest random dispersal by basidiospores and outbreeding within the population.", Pilotti et al. 2003
- 2012, Rees al. Are showing that basidiospores seems to have an important effect on disease spread. However, some identical isolates obtained from neighbor trees are not excluding the clonal propagation.
- Over 311 samples tested in this study, only five samples were identified as clones.
- Longest distance between 2 samples: 690 km

Mainly spread by sexual reproduction (basidiospores)

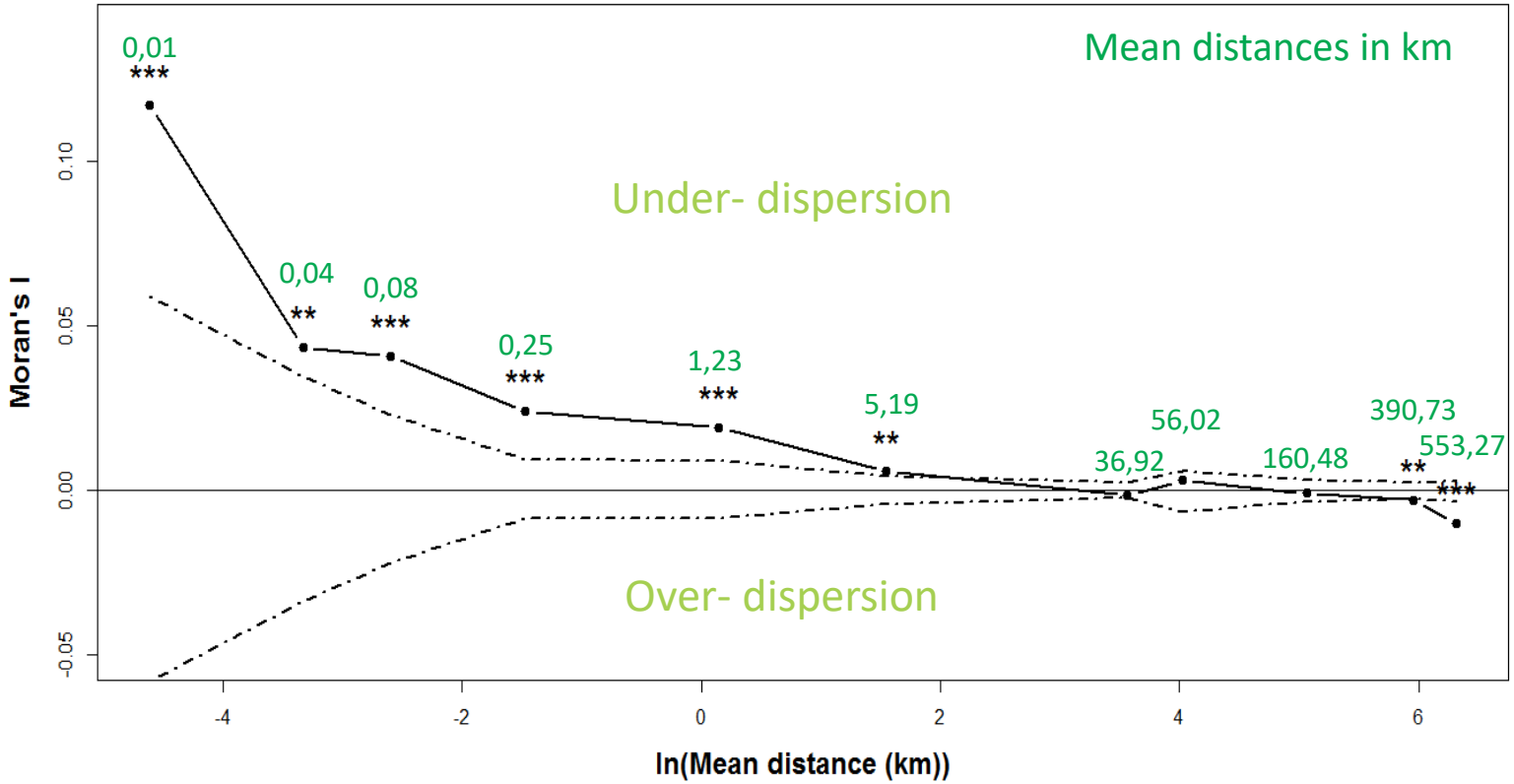
Clonal dispersal seems not to be dismissed

Mercière M., 2015

Dispersal abilities

- Spatial autocorrelation analysis of genetic and geographical distance in *Ganoderma boninense* based on Moran's *I*.
- Similar alleles under represented on distance between 0 and 10 km (plantation scale)
- Similar alleles over represented on distance between 350 and 690 km

DISPERSION POTENTIAL OF SPORE IS ABOUT MORE THAN 500 KM

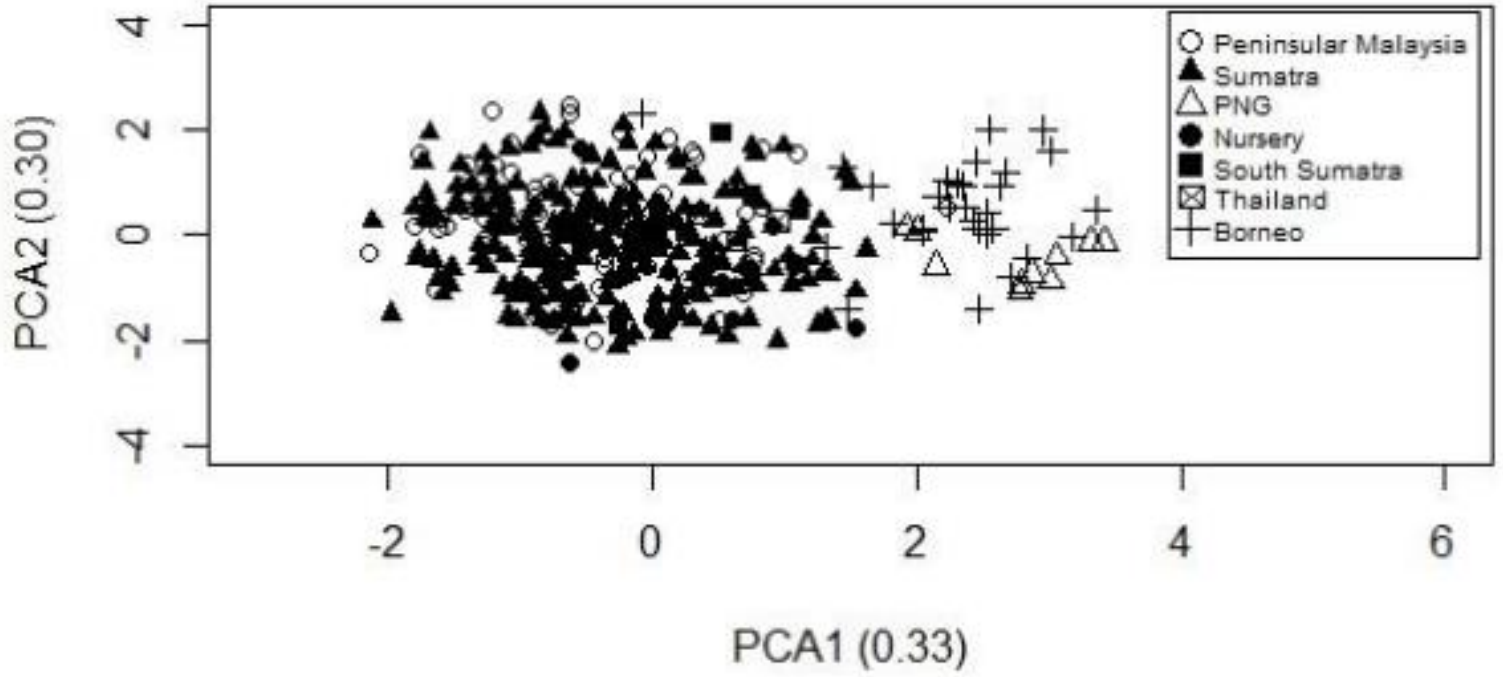


Dashed lines: 95% CI ; *** P < 0.001; ** P < 0.05.

Mercière *et al.*, Fungal Biology 2017

Demographic history

- Population of *Ganoderma* between peninsular Malaysia and Sumatra seems to be part of an homogenous population
- *Ganoderma* isolates from Borneo and PNG seems to segregate together
- Some Borneo samples are showing genetic similarities with Sumatra and peninsular Malaysia population



Mercière *et al.*, Fungal Biology 2017

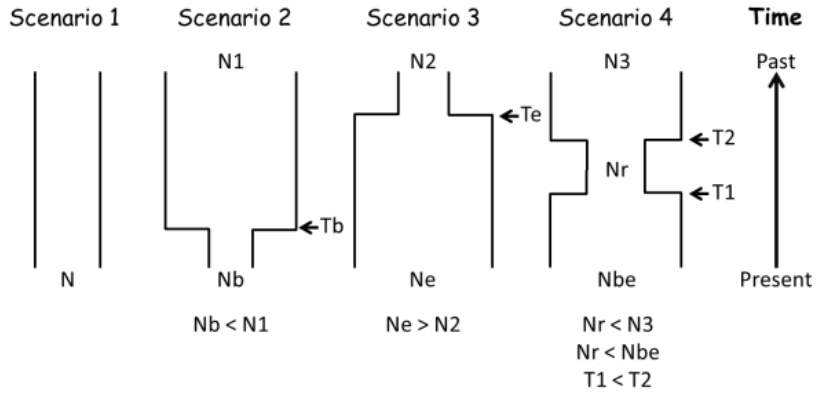
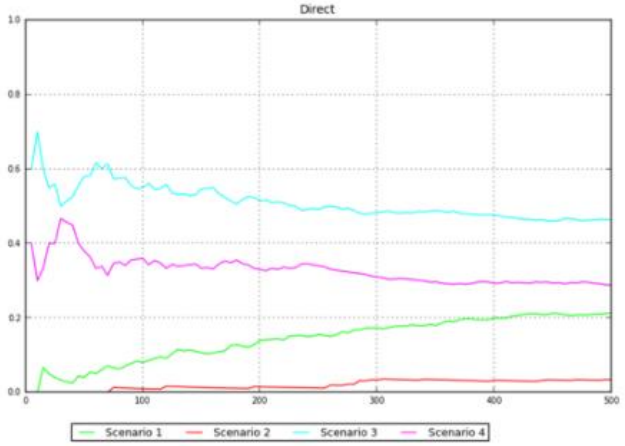


Figure 4. Demographic scenario for *Ganoderma boninense* in peninsular Malaysia and Sumatra using ABC approach as implemented in DYIABC 2.0.4 software by Cornuet et al. (2014). Scenario 1: evolution of a constant size *N* population. Scenario 2: population of size *N1* undergoes a bottleneck step *Tb* generation ago causing a significant reduction in the current population size *Nb*. Scenario 3: population of size *Ne* experiences a population expansion event from *Te* generation ago to actual population of size *N2*. Scenario 4: population of size *N3* undergo a bottleneck event *T1* generation ago causing a reduction in population size *Nr* followed by a population expansion *T2* generation ago to reach actual population size Nbe.

Table 2 – Posteriors parameter estimation for scenario 3 and scenario 4.

Scenario	Parameter	Mean	Median	Mode	q025	q975	Mean bias	Fact2
Scenario 3	Ne	52 700	49 800	37 000	12 800	97 200	0.196	0.914
	Te	3260	2370	769	81	9440	3.194	0.716
	N2	1780	1360	604	56.6	6500	0.629	0.718
	Âµmic	2,95E-04	2,19E-04	1,10E-04	1,04E-04	8,41E-04	0.270	0.838
	pmic	0.213	0.217	0.221	0.11	0.295	0.063	0.996
Scenario 4	Nbe	43 200	37 900	12 000	5450	95 900	0.246	0.9
	T1	2250	1810	552	91.7	6890	3.517	0.632
	Nr	800	569	218	55.9	3080	1.06	0.648
	Âµmic	4,49E-04	3,96E-04	1,43E-04	1,15E-04	9,70E-04	0.224	0.854
	pmic	0.202	0.201	0.172	0.113	0.294	0.077	0.998

Scenario 3: (Ne) Population size after expansion step, (Te) Time since beginning of expansion state in generation number, (N2) Population size before expansion, (Âµmic) mean mutation rate, (pmic) number of repeat motifs added or removed from the microsatellite in each mutation step. Scenario 4: (Nbe) Population size after expansion step, (T1) Time since beginning of expansion state in generation number, (Nr) Population size before expansion.



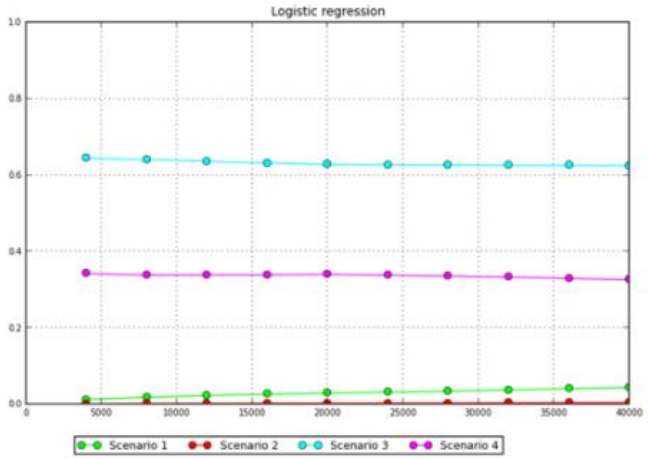


Figure 5. Scenarios comparison based on posterior probabilities estimation. A show results obtained from direct approach and B from logistic regression method.

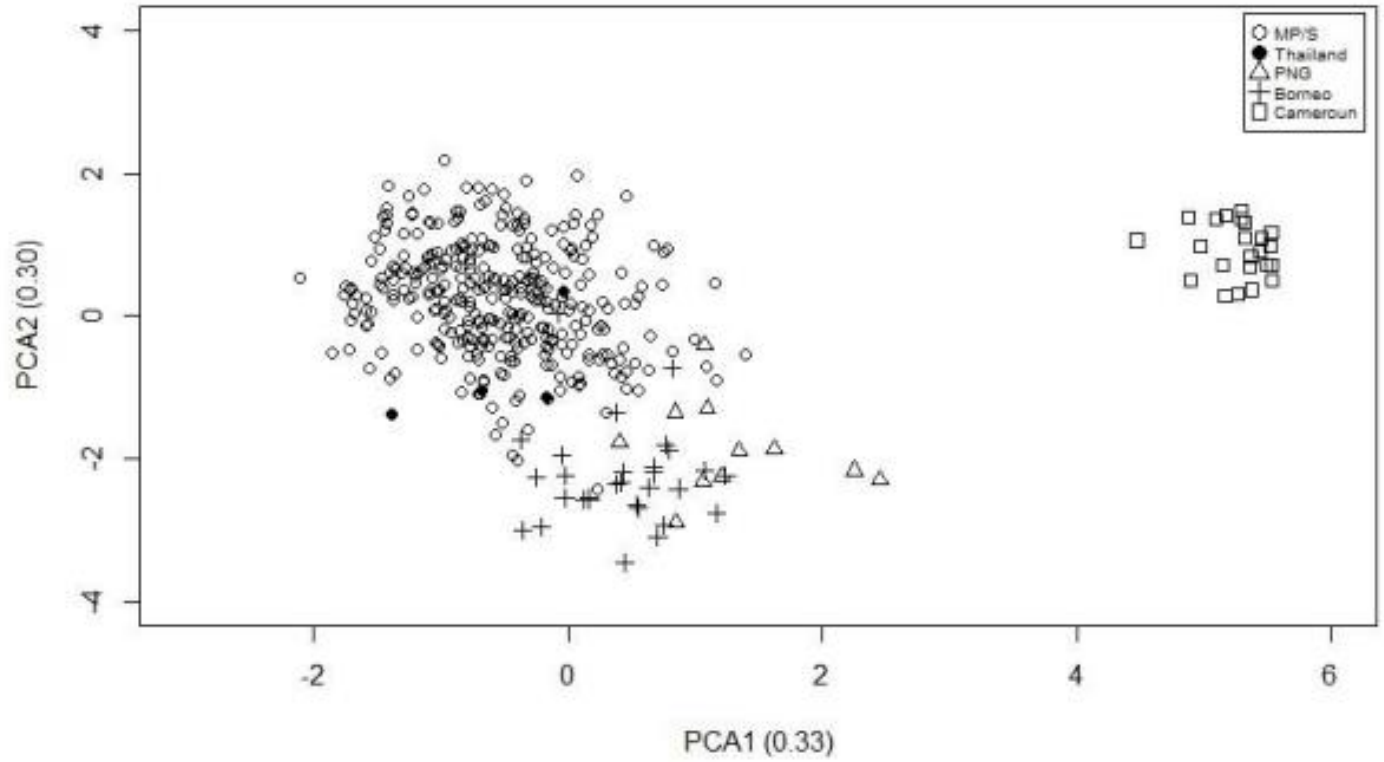
- Scenario 3 seems to be the most probable scenario but scenario 4 cannot be abandoned (both scenario explain 98%)
- Expansion seems aged from same period regarding both scenario 3 and 4
- Taking a generation every 4 to 7 years, each scenario predict an expansion time between 12 800 and 22 820 year ago (last glacial age)

Mercière *et al.*, Fungal Biology 2017

What if we had some isolate from African continent?

- Cameroun isolates appeared to be genetically far from Asian population

IS GENETIC RESISTANCE BREED IN ASIA WILL FIT AFRICAN CONDITIONS?



Mercière *et al.*, phd 2015

II. Host interaction: The basal stem rot

Foliar syptoms

Multiple unopen spears - Drying of lower palms - Appearance of a palm skirt around the stem



Stem syptoms

Crack - Spongy structure - Infected tissue with white color before total degradation

SLS structure on roots and bowl

Fruiting bodies

A brief history of Basal stem rot

- Firstly described in Congo (Wakefield, 1920)
- First description In Malaysia 1931 (Thompson) but thought to be not economically important
- Reported on 5 year old palm since 1957-58 (25 years after first description in Malaysia)
- In 1981, “the most annihilating disease of fields palms causing significant losses in Southeast Asia” (Turner et al., 1981)
- Nowadays, Widely spread in South-East Asia
- Developing more and more in Africa (Nigeria, Cameroon, RDC…)
- Start to emerge in South America

EL PODER TRANSFORMADOR DE LA PALMA DE ACEITE

In south-east Asia BSR can kill up to 81% of a 13 year plot and a maximum of 39% have been recorded in a CDC plot of 16 years old

Control strategies

IPM

1. Cultural practices development

- Dispersal potential and strategies of the pathogen
- Need to understand life cycle of the pathogen

2. Chemical fight development

- Need to study and understand biology and physiology of the pathogen (life cycle, biochemical composition, epidemiology)

3. Genetic development of resistant varieties

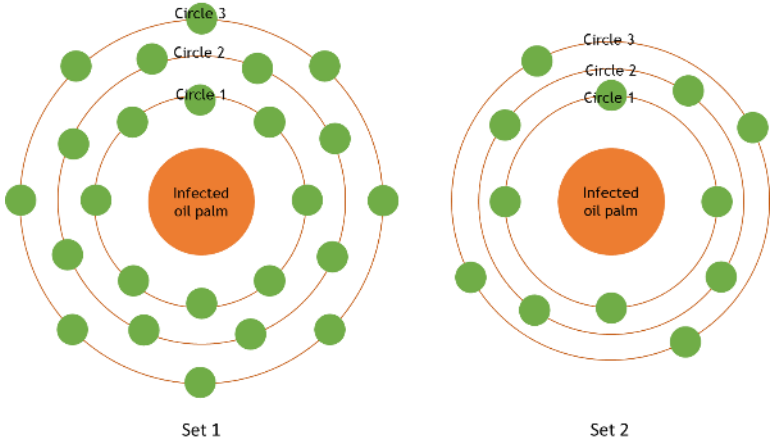
- Need to find genetic source of resistance
- Need to evaluation the evolution potential of the pathogen (structure, diversity…)

4. Biological control (control species)

- Need to study biological composition of the ground
- Find a potential antagonistic effect

Cultural practices

- Cultural practices are impacting spread of the disease and reinforcement of pathogen density in the field

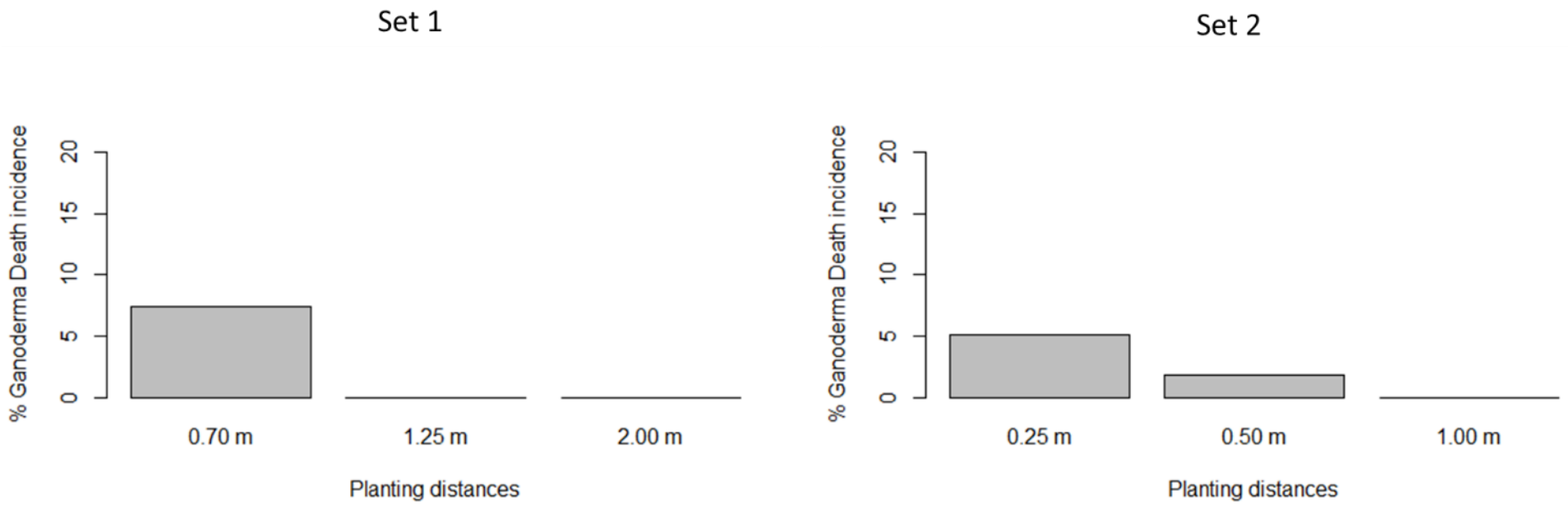


	Circle 1	Circle 2	Circle 3
Set 1	0.70	1.25	2.00
Set 2	0.25	0.50	1.00

Set 1

Set 2

Mercière *et al.*, PIPOC 2019

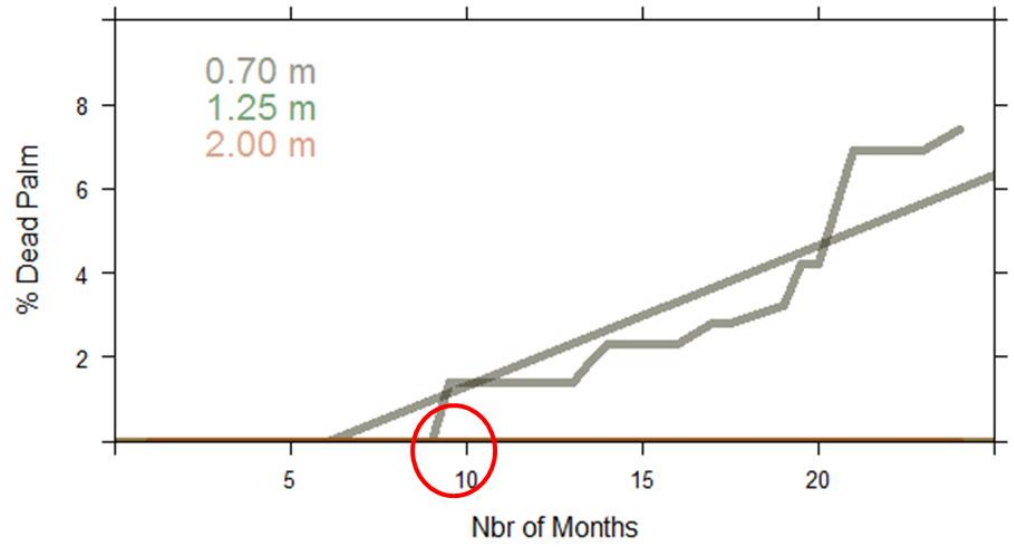


- Set 1 have shown dead palm due to *Ganoderma* only on first circle with a value of 7.41% after 26 months
- Set 2 have shown dead palm due to *Ganoderma* on circle 1 and 2 with respective incidence of 5.09 and 1.85% after 22 months

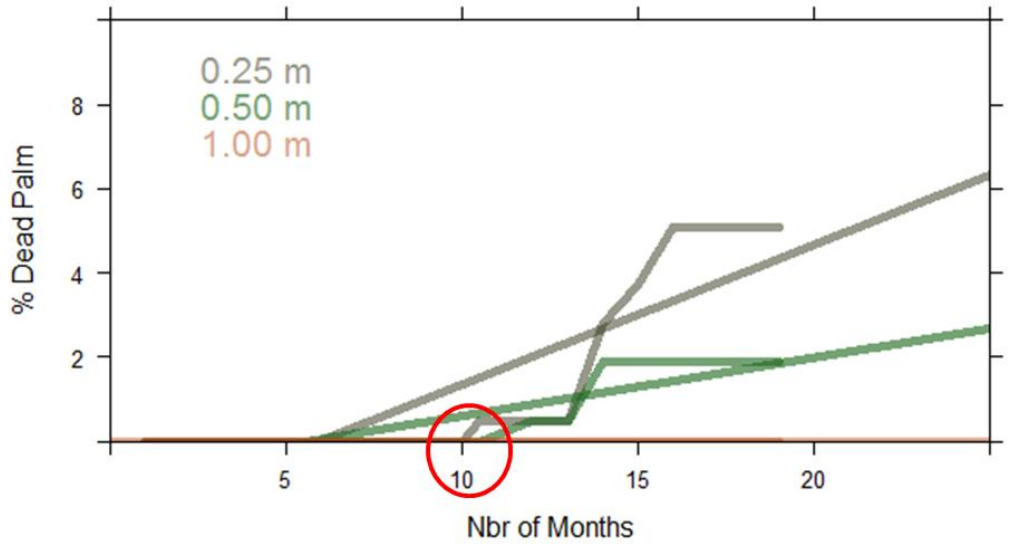
Mercière *et al.*, PIPOC 2019

- Seems to have a limit to first death observed but not correlated to planting distance (around 10 months)
- Seems to have a limit distance for *Ganoderma* death impact (> 0.70 m)
- Correlation of 99.8% with a p-value < 0.001 (2.24e-10) between the two sets

Set 1



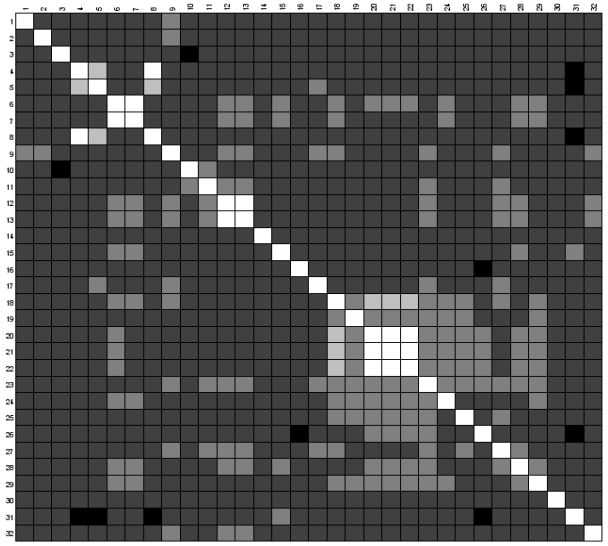
Set 2



Mercière *et al.*, PIPOC 2019

Sanitation Impact

Borneo (East Sabah)



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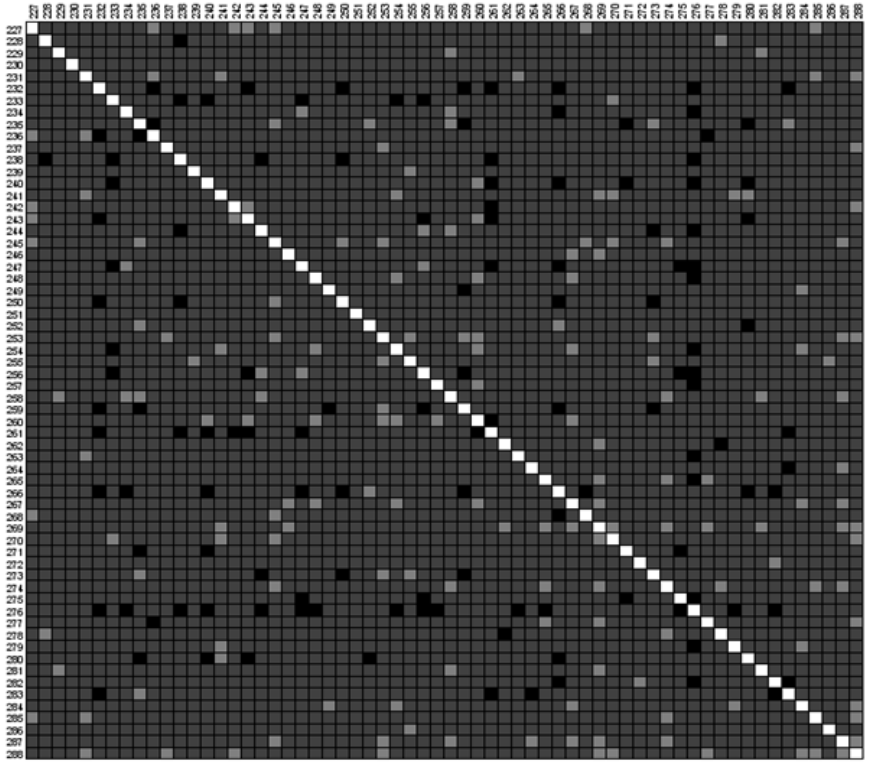
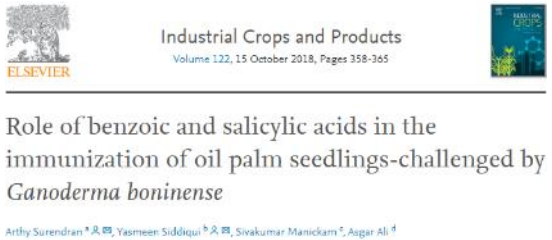


- Sampling of isolates from plantation with sanitation procedure (Mata Pau, Sumatra) and without sanitation procedure (East Sabah, Borneo)
- Sanitation procedure = evacuation of the infected part of the stem + excavation of root bowl
- Data obtained from genotyping of each plantation isolate allowed to obtain genetic distance between each isolate per plantation (matrix ordered by distance between isolate)

Mercière M., 2015

- Sanitation seems to have an impact on development of the pathogen
- No sanitation can increase pathogen transmission

Chemical control


Industrial Crops and Products
Volume 122, 15 October 2018, Pages 358-365

Role of benzoic and salicylic acids in the immunization of oil palm seedlings-challenged by *Ganoderma boninense*

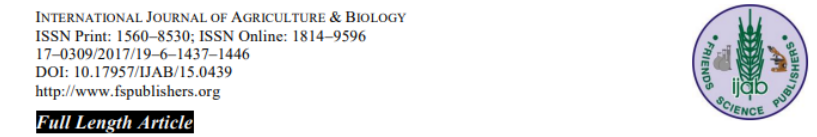
Arthy Surendran, Yasmeen Siddiqui, Sivakumar Manickam, Asgar Ali


The Plant Pathology Journal
http://ppjonline.org

Plant Pathol J. 2016 Oct; 32(5): 396–406. PMCID: PMC5051558
Published online 2016 Oct 1. doi: 10.5423/PPJ.OA.03.2016.0052 PMID: 27721689

Control of Basal Stem Rot Disease in Oil Palm by Supplementation of Calcium, Copper, and Salicylic Acid

M. Shahul Hamid Rahamah Bivi,[1] Adamu Saidu Paiko,[2] Ahmad Khairulmazmi,[3,*] M. S. Akhtar,[4] and Abu Seman Idris[1]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http://www.fspublishers.org

Full Length Article

The Antagonistic Effect of Phenolic Compounds on Ligninolytic and Cellulolytic Enzymes of *Ganoderma boninense*, Causing Basal Stem Rot in Oil Palm

Arthy Surendran[1], Yasmeen Siddiqui[1*], Halimi Mohd Saud[2], Nusaibah Syd Ali[3] and Sivakumar Manickam[4]


Journal of Applied Microbiology
Journal of Applied Microbiology ISSN 1364-5072

ORIGINAL ARTICLE

Inhibition and kinetic studies of cellulose- and hemicellulose-degrading enzymes of *Ganoderma boninense* by naturally occurring phenolic compounds

A. Surendran[1], Y. Siddiqui[1], N.S. Ali[2] and S. Manickam[3]

Chitosan-Based Agronanofungicides as a Sustainable Alternative in the Basal Stem Rot Disease Management

Farhatun Najat Maluin, Mohd Zobir Hussein*, Nor Azah Yusof, Sharida Fakurazi, Abu Seman Idris, Nur Hailini Zainol Hilmi, and Leona Daniela Jeffery Daim

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Crop Protection
Volume 67, January 2015, Pages 151-159

Silicon treatment in oil palms confers resistance to basal stem rot disease caused by *Ganoderma boninense*

Nor Ismail Najihah, Mohamed Musa Hanafi, Abu Seman Idris, Md Abdul Hakim

- Since 2015 about 8 papers published on role of chemical compound as protectant against *Ganoderma* infection
- Potential high impact on environment (RSPO)
- Only limited possibilities to apply it on large scale as industrial plantation

Biological control

- Most of studies done in nursery = No field validation
- 3 fungal species: *Trichoderma sp., Scytalidium parasiticum, Hendersonia*
- 3 Bacterial species: *Burkholderia sp., Pseudomonas aeruginosa, Serratia marcescens*
- Microorganism highly specific from micro-environmental condition (difficult to adapt to large industrial plantation)

Genetic selection

- Selection for resistant material to disease: creation of a material with partial resistance to *Ganoderma*

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III. Conclusion

- *Ganoderma* species are spread all over the world. Eradicating fungus is not possible
- Possibility of spore dispersal over 500 km
- Different context between Asia, Africa and potentially South America
- Problem with early detection of the disease (root stage)
- Curative chemical should be used in addition to early detection to succeed healing of the tree. But task too costly and hard to handle for industrial plantation (can be used to saved collection trees)
- Preventive chemical can have a high impact on environment
- Sanitation can have a positive but limited impact on pathogen development
- Only durable method until now: Cultural practices + genetically selected material

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Thanks