T1 - Cocoa cultivation: Innovative Approaches and Practices for Sustainable Production

Using mathematical Modeling to improve control strategies in the cocoa and black pod disease pathosystem

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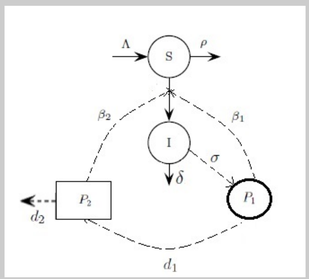
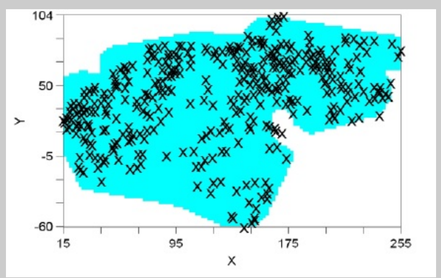
Black pod rot of cocoa, due to *Phytophthora* spp. is a major constraint in cocoa production and much research attention has been dedicated to to assure its control. Nonetheless, there are still numerous questions regarding the factors that govern the disease's dynamics. Here, we explore the use of mathematical modelling to understand the spatial dynamics of black pod disease caused by *P. megakarya* and notably the impact of shade on disease dynamics. The results were exploited as a base for an in-vitro investigation on the impact of light on growth and sporulation of *P. megakarya*. Shading data collected in the cocoa plot led to refined numerical simulations of disease dispersion and to identify a greater number of infected pods located in areas of the plot with higher shading values. Following the investigation on the effect of shading on system dynamics, the effects of different light wavelengths on *P. megakarya* biology (growth and sporulation) were assessed. Experiments revealed that all studied strains grew relatively better in the dark compared with exposure to light. However, it was noted that in general light was a stimulating factor for *P. megakarya* sporulation.

A model to simulate the spatial spread of black pod



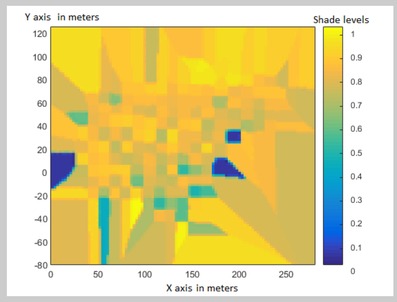
(A) Black pod spatio-temporal model



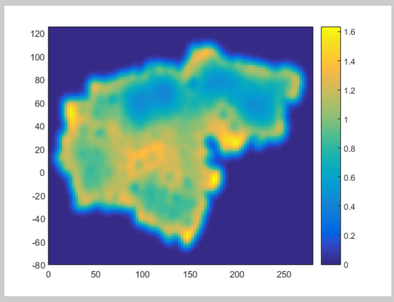
(B) Plot with sampled cocoa trees

- From the temporal model [1], a spatial epidemiological model describing the dispersion of the epidemic in the field was developed.
- Some modifications have been made to the temporal mechanistic model, namely : the grouping of susceptible compartments of all stages of maturity, the simplification of the infection forces and the addition of dispersion coefficients in the two spore compartments.

Assessing the impact of shade on the system



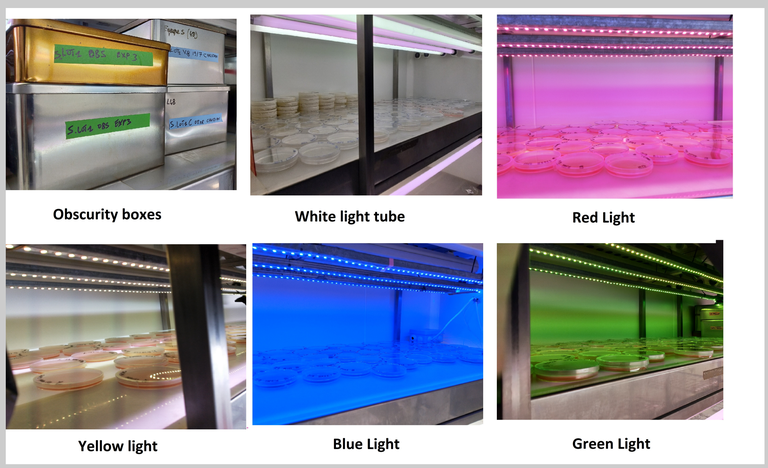
(C) Shading intensity levels in the plot



(D) Susceptible compartment evolution at $t = 120$

- Shading data collected in the cocoa plot (B) led to a better fit of the spatio-temporal model over epidemiological data and also allowed the identification of a greater number of infected pods located in areas of the plot with higher shading intensity.
- Numerical simulations of disease disperal also reveals that epidemics outbreaks in the plot where located in areas of the plot with higher shading intensity.

Experimental design to study light effect on *P. megakarya*

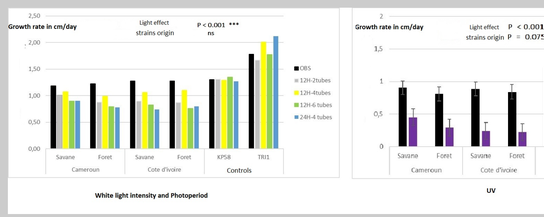


(E) Strains under different light conditions.

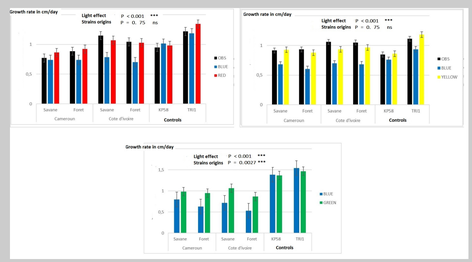
- 29 *Phytophthora* strains selected from Cameroon and Cote d'ivoire.
- 3 replicates per strains in all the experiment and 2 control strains identified
- Obscurity used as light control in all the experiments
- Zoospores production was determined by haematocymeter after 10 incubation days.

Data analyis : Through Anova, the effect of white light intensity, photoperiod and different light colors/wavelengths effects on *Phytophthora* strains (growth and sporulation) were investigated.

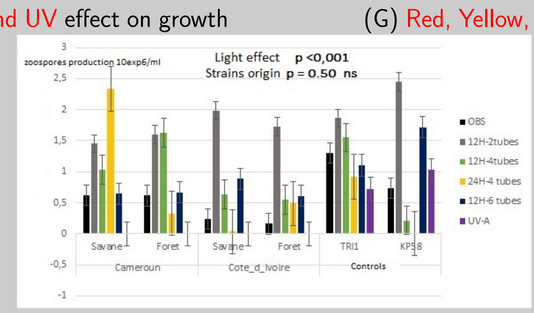
Major results



(F) White light and UV effect on growth



(G) Red, Yellow, Blue and Green light effect on growth



(H) Zoospore production under different light conditions

- All of the studied strains showed significantly faster growth in darkness (F, G).
- Strain growth rates were significantly reduced after exposure to increasing photoperiods and light intensities (F, G).
- Blue light and Ultra-violet significantly reduced *P. megakarya* strains growth and sporulation compared to other wavelengths tested (G).
- Light has proven to be a stimulating factor for zoospore production (H).

Dicussion and Conclusion

Through a multidisciplinary and systemic approach, this study contribute to the identification of key factors for black pod disease epidemic outbreaks. Qualitative properties of our system and experiment seem to be in good agreement with the literature [2], [3]. Shade effect on the system dynamics can be explained by more favorable environmental conditions (low temperature and high humidity) for *P. megakarya* spores development. The experimental design results agrees with the results of the spatio-temporal model regarding shading effect. The increase in the growth rate of *P. megakarya* in the dark and increased sporulation under light conditions may help explain why shaded or heterogeneously shaded systems are more favorable to *P. megakarya* development. Further investigation need to be carried out to clarify shading effect in disease dynamics and strategic management of plot shading in the field may be encouraged as control measure.

[1] Nembot C, Takam P, ten Hoopen M Dumont Y, Modeling the temporal evolution of cocoa Black pod rot disease. Applications in terms of control. Under review. 2017.

[2] Blaha G. 1983. Effet de la lumière sur *Phytophthora palmivora* et *Phytophthora megakarya*, agents de la pourriture brune des cabosses du cacaoyer. Etude préliminaire du phénomène de photo-inhibition observé sur *Phytophthora megakarya*. *Café, Cacao, Thé*. 27 : 91-112.

[3] Englander L., Browning M., Tooley W. P. 2006. Growth and sporulation of *Phytophthora ramorum in vitro* in response to temperature and light. *Mycologia*. 98 : 365-373.