Acorbat Revista de
Tecnología y Ciencia

Designing innovative spatial strategies to control black leaf streak disease of banana through modelling approach

Catherine Abadie[1,2,5]; Eduardo Corrales B[2]; Béranger Decouture[1,2]; Marta Zaffaroni[3]; Jean-François Rey[3]; José Guzmán[4]; Edgar Valverde[4]; Nancy Chaves[4]; Loup Rimbaud[3].

[1]CIRAD-PHIM, Costa Rica; [2]CATIE, Turrialba, Costa Rica; [3]INRAE-Plant Pathology, Avignon, France; [4]CORBANA, Costa Rica; [5]PHIM, University of Montpellier, CIRAD, INRAE, Institut Agro, IRD, F-34398 Montpellier, France

***Autor de Correspondencia:**
Catherine Abadie
catherine.abadie@cirad.fr

Contribución:
Tecnológica

Sección:
Fitosanidad

Recibido:
15 Diciembre, 2023
Aceptado:
15 Enero, 2024
Publicado:
16 Abril, 2024

Cita:
Abadie C, Corrales BE, Decouture B, Zaffaroni M, Rey JF, Guzmán J, Valverde E, Chaves N and Rimbaud L. 2024. Designing innovative spatial strategies to control black leaf streak disease of banana through modelling approach. *Acorbat Revista de Tecnología y Ciencia* 1(1): 25
https://doi.org/10.62498.ARTC.2425

RESUMEN

Realizar experimentos para evaluar estrategias espaciales para el control de Sigatoka negra (SN) a escala de finca es complejo. La modelización es un enfoque clave para identificar escenarios innovadores que permitan reducir el uso de pesticidas y, al mismo tiempo, controlar la enfermedad de forma eficiente y sostenible. Para lograr este objetivo, se evaluó la eficacia de estrategias basadas directamente en la aplicación de fungicidas o en cultivación de cultivares resistentes. Para ello, se adaptó un modelo espacialmente explícito para simular epidemias de SN en un paisaje agrícola real de 300 hectáreas en Costa Rica. Se están realizando más de 11.000 simulaciones de estrategias y se identificarán los mejores escenarios que podrían probarse en el campo.

Palabras clave: simulación epidemiológica, escenarios espaciales, control sostenible, fitosanidad.

ABSTRACT

Experimentations to evaluate spatial strategies at the scale of a production basin to control Black leaf streak disease (BLSD) is difficult to implement. Modelling is a key approach to identify innovative scenarios to reduce the use of pesticides while efficiently and sustainably controlling the disease. To achieve this aim, we assess the efficacy of strategies directly based on fungicide applications or based on the deployment of resistant cultivars. For that, we adapted a published spatially-explicit model to simulate BLSD epidemics in a real 300-ha agricultural landscape of Costa-Rica. More than 11,000 simulations of strategies are undergoing and the best scenarios will be identified to be further tested in the field.

Keywords: epidemiological simulation, spatial scenarios, durable control, phytosanity.

INTRODUCTION

Black leaf streak disease (BLS) is the main constraint of banana production for exportation by damaging leaves and impacting fruit ripening and yield (Guzman et al., 2018). This disease is managed by frequent aerial applications of fungicides (from 15 to 50 depending on countries). Due to fungicide resistance and considering environmental impacts, such frequent fungicide strategies are not durable. As experiments are difficult to implement at the scale of a production basin (e.g. several hundred hectares), modelling is a key approach to identify innovative scenarios to reduce the use of pesticides while efficiently and sustainably controlling the disease.

The global aim of the study is to assess the efficacy of different strategies to reduce pesticide use to manage Black Leaf Streak Disease (BLSD) of banana by using a mathematical spatially-explicit model. More particularly, two different strategies are evaluated on a real production landscape (farm scale): (i) one directly based on fungicide applications (with reduction of application frequency, spatial coverage, or dose); (ii) one based on the deployment of resistant cultivars (with the increase in spatial coverage, resistance efficiency, choice of target pathogen traits).

MATERIALES Y MÉTODOS

The generic epidemiological mathematical spatially-explicit model *landsepi* (Rimbaud *et al.*, 2018) was adapted to simulate BLSD epidemics in a real agricultural landscape. The model is structured in 4 compartments (Healthy, Latent, Infectious, Removed) representing the sanitary status of plant units. The adaptation has consisted in modifying plant growth to banana (leaf emission and successive crop cycle) and 30 BLSD parameters coming from either literature or personal data (e.g. for CIRAD hybrid component).

Thirty-three spatial-temporal strategies were defined following discussion with growers (CORBANA team) in October 2022. The proposed strategies aim to reduce the index of fungicide treatment (fungicide active ingredient per ha and per year). Two main strategies were defined (Figure 1): (i) a direct fungicide reduction via a smaller of frequency of application (applied every 5, 10 and 15 days), a smaller spatial coverage (25, 50 or 75%), or a smaller dose which reduces treatment efficiency (25, 50, 75 and 100%); (ii) the replacement of the susceptible commercial variety by resistant hybrids with increasing spatial coverage (25, 50, 75%), increasing resistance efficiency (25, 50, 75 and 100%), or different choices of target (pathogen traits). We also simulate the effect of CIRAD 938, an elite hybrid of the CIRAD breeding program of Guadeloupe, for which the resistance parameters are known.

Each scenario will be simulated 30 times on the real 347-ha banana production basin of the Finca San Pablo of CORBANA, in Costa-Rica. The area represents 295 independent subunits. The yield and epidemiological control (Green Leaf area) provided by the simulated scenarios for 3 crops cycles (3 years) will be compared between of the scenarios. The 11,760 simulations of the yield and epidemiological control, issued from 392 combinations of scenarios of direct reduction of fungicides or deployment of new resistant varieties, are undergoing and will be statistically analysed by adjusting linear mixed models to compare the efficacy of the 33 spatial-temporal strategies. The significant differences will be based on the multiple comparisons LSD Fisher test.

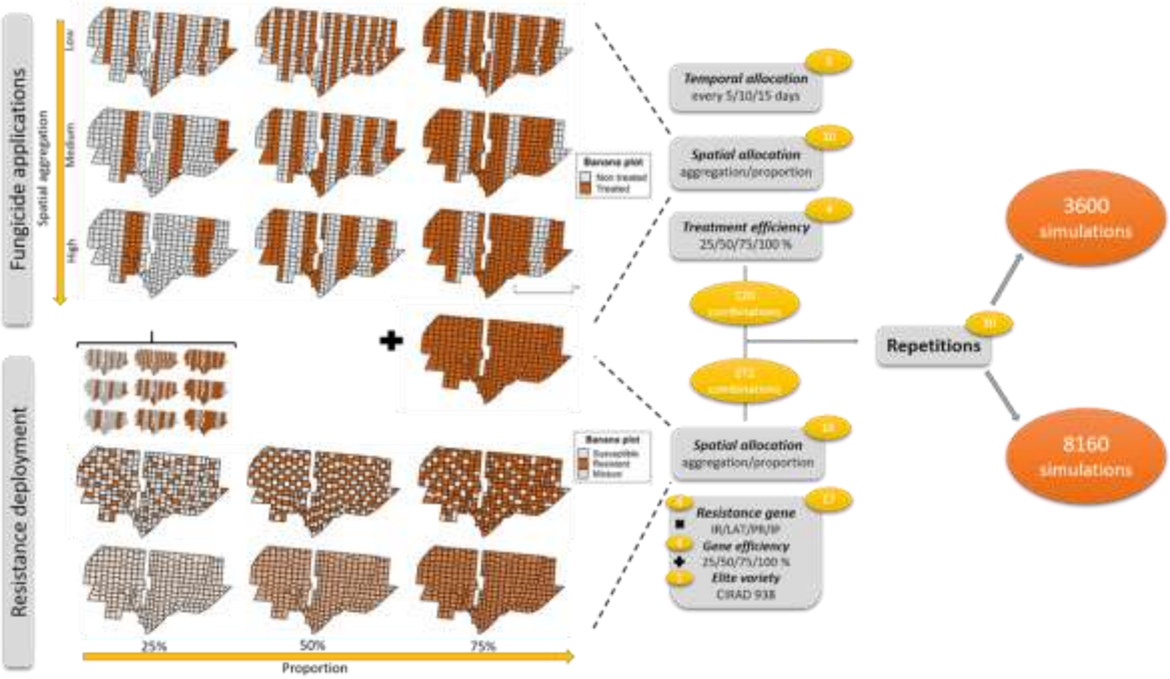

Figure 1. 50 spatiotemporal scenarios of reduction of pesticides either (i) directly by reducing fungicide coverage and frequency or fungicide doses, or (i) indirectly using resistance deployment by spatial scenarios replacing the commercial susceptible variety by a resistant variety. White and orange polygons represent non-treated and treated plots (either with fungicide application or using cultivar resistance), respectively.

RESULTS AND DISCUSSION

The parametrization of the *lansepi* model for BLSD allowed to obtain realistic curves of dynamics of the 4 compartments (Healthy, Latent, Infectious or Removed). The Figure 2 shows that the dynamics of the Healthy compartment for the susceptible variety Cavendish varied from 30% to 60% of the carrying capacity (i.e. the maximal number of hosts in the landscape) whereas the other compartments can reach up to 20% for the latent and infectious states, and up to 55% for the removed state. These curves allowed to calculate a Green Leaf area (GLA) of 0.74 $day^{-1}.m^{-2}$ (approximately 50% of the GLA in absence of disease), an AUDPC=0.53, and an average yield of 17.4 t ha^{-1} $season^{-1}$ (60% of the yield in absence of disease).

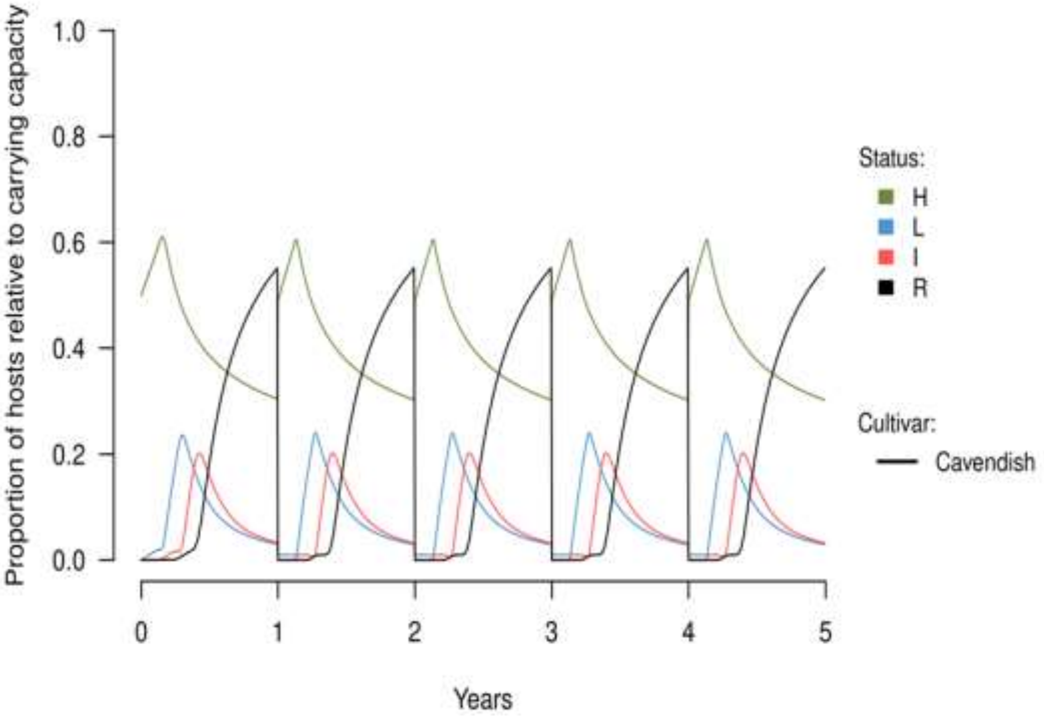

Figure 2. Epidemic dynamics in a fully susceptible banana landscape.

After the parametrization step, numerical simulations have started and are still undergoing. No numerical results can be presented for now. The outputs of the 11,760 will be statistically analysed with linear mixed models. The best scenarios of direct fungicide reduction and resistance varietal deployment to manage BLSD while sustaining an acceptable yield will be identified in 2024. The feasibility of these spatiotemporal strategies will be discussed with banana growers to allow a future field-validation and adoption.

CONCLUSIONS

To control BLSD in a real 300-ha farm, a modelling approach has been developed and allows the comparison of 50 spatial and temporal strategies of fungicides reduction either directly related with fungicide or related with the deployment of resistant varieties. This approach will allow to identify the most promising scenarios efficient in the control of the disease and allowing an appropriate yield.

REFERENCIAS

1. Guzman M, Perez-Vicente L, Carlier J, Abadie C, De Lapeyre de Bellaire L, Carreel F, Marin DH, Romero RA, Gauhl F, Pasberg-Gauhl C, and Jones DR. 2018. Black Leaf Streak. In: Jones DR (Ed.), Handbook of Diseases of Banana, Abacá and Enset. CABI, Oxon, UK, pp. 41 – 115.
2. Rimbaud L, Papaïx J, Rey J-F, Barrett LG, Thrall PH. 2018. Assessing the durability and efficiency of landscape-based strategies to deploy plant resistance to pathogens. PLoS Comput Biol 14(4): e1006067. https://doi.org/10.1371/journal.pcbi.1006067