Modelling regional scale polygenic fungicide resistance and grower behaviour to inform resistance management for sustainable agriculture

Project Code: ICS-PLANT-NC

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Industrial Partner: Syngenta Crop Protection (part of Syngenta Group)

Research area: Mathematical modelling & plant disease epidemiology

BBSRC DTP main strategic theme: Bioscience for sustainable agriculture and food

BBSRC DTP secondary strategic theme: Transformative technologies

Project outline:

Fungicide treatments are often essential to maintain crop health and yield, and so are routinely deployed, at least in the developed world. However, applying chemical disease control exerts a very strong selection pressure on plant pathogens, which evolve in response. The emergence and spread of crop pathogens resistant to chemical disease control threatens not only crop yields, but also food security. In this project we have joined forced with an industry partner – Syngenta Crop Protection – to use mathematical modelling to pursue the common goal of developing strategies to better understand and manage this threat. The project team is consisted of academics and practitioners, with expertise ranging from plant disease epidemiology to mathematical modelling to statistics to practical field application.

Resistance management – optimising fungicide deployment to delay the emergence or spread of resistant pathogen strains – has been studied for decades. But most mathematical models of fungicide resistance are highly simplified, considering a single monogenic trait, subject to selection by a single chemical, within a single spatially isolated field and facing a single disease pressure year-on-year (Elderfield et al 2018). This is not entirely realistic. For many fungicide/pathogen combinations, resistance is polygenic, characterized by gradual shifts in the pathogen population. Dispersal of inoculum means that resistance management decisions made by any single grower affect all other growers at regional scales (Fabre et al 2021). Since crop pathogens respond strongly to the environment, particularly weather, disease pressures vary by location and from year-to-year (Del Ponte et al 2006). And chemicals are often combined in complex spray programmes, with selection for different resistances occurring simultaneously both singly and in combination (Taylor & Cunniffe 2023a), and typically with precise timings of sprays based on results from decision support systems (Cucak et al 2021).

Building on two recent BBSRC DTP studentships in my laboratory, we will develop a new framework to optimise fungicide resistance management strategies while accounting for these complexities. We will use two important, contrasting case studies: Asian soybean rust (ASR) in Brazil & Septoria leaf blotch (SLB) in Western Europe. For ASR, we will build on Syngenta's in-house model, and the project benefits from the involvement of Emerson Del Ponte, an expert in ASR epidemiology (see, for e.g., Dalla Lana et al 2018). For SLB, we recently developed the first model of polygenic fungicide resistance (Taylor & Cunniffe 2023b). For both systems, Sygenta can supply access to laboratory/greenhouse and field experiments for further model development and fitting. This will allow us to extend the models to include regional spread, the effect of environmental drivers, and complex spray programmes (including integration with decision support systems). Grower behaviour will also be included, building on work showing how plant disease epidemiology and economics can be integrated via game theory (Murray Watson et al 2022a & b).

Training would be provided via this project in i) mapping a complex biological system to a parsimonious mathematical model; ii) modern methods for simulating epidemiological models; iii) high performance computing, via use of a computing cluster; iv) experience of applying mathematics to a biological system; v) methods of fitting complex mathematical models to spatio-temporal data; vi) testing ecological and epidemiological hypotheses via mathematical modelling.

The project would be well suited to a student with a background in mathematics, engineering, physics, or theoretical ecology, ideally with prior knowledge of computer programming, motivated to transition to work on biological problems. However, students with a background in wet-lab biology have enjoyed and been very successful in my laboratory in the past. Any such candidates with a strong interest in making a transition to mathematical modelling are also very much encouraged to get in touch to discuss. The successful candidate will have an opportunity to gain experience of working both in academic and industry setting. The candidate will be based at the University of Cambridge, with a three-month placement in Syngenta in Warwick.

References

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2. Dalla Lana, F., … & Del Ponte, E.M. (2018) Meta-Analytic Modeling of the Decline in Performance of Fungicides for Managing Soybean Rust after a Decade of Use in Brazil. Plant Disease. 102:807-817.

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