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# Modelling plant enemies adaptation

## Dynamics and evolution of life traits of plant pathogens and crop pests

### ABSTRACT

The development of a more sustainable agriculture is at the core of current ecological and societal concerns. Facing this scientific challenge we have to pave the way to a more durable use of ecologically-acceptable management strategies of plant pathogens and pests such as e.g. the use of resistant plant varieties, biocontrol agents or new generation pesticides. So far most theoretical developments concerning the durability of crop management strategies have focused on controlling pest and pathogen population dynamics. In this project, we alternatively argue that the long-term sustainable regulation of plant pathogens and pests may critically depend on the evolution of their life histories, what is rarely taken into account. Life history theory deals with the strategic decisions of organisms along their life-time. In particular it is concerned with the timing of reproduction, the way organisms exploit hosts or forage resources, and how they manage their growth schedule. For plant pathogens and pests, all these traits have a strong influence on the damage they cause to agricultural crops and how they disseminate in the environment, but they have never been properly modelled.

This project has allowed triggering extensive collaborations between 5 young researchers in phytopathology, theoretical evolutionary ecology and mathematics, their associated students and post-docs and more generally their respective teams.

To date, we have set the bases of a comprehensive theory of life history trait evolution of pests and pathogens based on optimal control modelling. For instance, we have shown that having a latent period, during which all resources extracted from host are allocated to within-host colonisation is optimal under a wide variety of conditions. We also show that pathogens that have different access to host resources should differ in their host exploitation strategy. Pathogens that rely on a finite amount of resource that is progressively consumed (e.g. necrotrophic foliar fungal pathogens) should first colonise host tissues and then dedicate fully to spore production, letting their within-host exploitation structure decay until the end of infection. In contrast, pathogens that benefit from a constant nutrient flow from their host (e.g. biotrophic fungal pathogen, aphids...) should rather continue ensuring the maintenance of their within-host exploitation structure after the onset of sporulation. Both strategies dramatically differ in the dynamics of spore production. One may therefore expect that they will have different epidemiological impacts. These models have been successfully validated by experiments carried out on two fungal pathogens of huge agronomical impact : the ascomycete Magnaporthe oryzae that is responsible for rice blast and the basidiomycete Melamspora larici-populina that causes poplar rust. To end with, these models allow envisaging how management tactics affecting different aspects of host-pathogen interactions will affect the selective pressures on host infection strategies.
A second line of the project was to embed these predictions in an adaptive dynamics framework, which enables both evolutionary history and population dynamics of pests and pathogens to be assessed under various environmental scenarios. To date, we focussed on models of evolution of infection strategies in a temperate environment (i.e., under annual seasonality formalised through semi-discrete models). As an example of the results obtained, we show, by analysing a seasonal consumer-resource system (e.g., herbivorous insects on plants), that the optimal foraging strategy, which could be qualified as a cooperative and sustainable use of resources, although stable in a population dynamics acceptation, is not evolutionarily stable in the long run. This strategy is indeed not immune to invasion by a more selfish strategy. The unbeatable (a necessary condition to evolutionnarily stability) foraging strategy tends to overexploit the resources to prevent deviants' invasion; as a consequence it is un-sustainable in the long term. Such a result is an example of the well-known "tragedy of the commons" and may offer a better understanding of explosive and devastating pullulations outbreaks of pests.

**Keywords :** Plant, Bio-aggressor, Evolution/domestication, Management strategy, Modelling

**Year :** 2009
**Project number :** 0902-013
**Type of funding :** AAP INRIA
**Project type :** AAP
**Research units in the network :** AIDA
**Start date :** 2009-07-06
**End date :** 2010-12-31
**Flagship project :** no

**Project leader :** Virginie Ravigne
**Project leader's institution :** CIRAD
**Project leader's RU :** BGPI-PHIM

**Budget allocated :** 19682.6177 €
**Total budget allocated ( including co-financing) :** 26962.49 €
**Funding :** RTRA

## PERSPECTIVES

The project is only halfway. The months to come will see the PhD defence of Audrey Andanson on "Evolution of aggressiveness in fungal plant pathogen: combining theoretical and empirical approaches", the publication of several papers and the hiring of Magda Castel (a former pre-doc student of this project) as a PhD student on the evolution of reproduction strategies in plant pathogens. The richness of the results obtained has largely convinced us that much attention should be devoted to the evolution of pathogen and pests life histories in response to management tactics. We therefore plan to continue the integration of models of life history evolution and epidemiological models with special interest in plant pathogens and pests. As an acknowledgement of these works and advances we received recently the financial support from the INRA to pursue the project over the next two years.