Fungicide resistance: invasion thresholds and optimal control strategies

Richard J. Hall[1] , S. Gubbins[2] and C. A. Gilligan[3].

Fungicide resistance is a major problem facing farmers worldwide, causing crop failure and massive economic losses annually. Mathematical models play a vital role in assessing the risk of invasion of resistant forms and in the design of practical fungicide application schemes.

Improving on existing work [3], we have developed a model that incorporates the dynamics of the host crop and quantifies how the amount, decay and timing of a fungicide dose affect selection for resistance [2]. The model structure is similar to those used to describe antibiotic resistance (e.g. [1]), and hence the results have broader applicability to drug and pesticide resistance in general.

We identify a threshold for the invasion of resistant forms in terms of two key parameters [2]: the fitness of the resistant strain relative to that of the wild-type in the absence of treatment; and the treatment efficacy (which summarizes how control inhibits pathogen survival and reproduction). The threshold is robust to demographic stochasticity and periodic fungicide effects.

In the absence of resistance, high fungicide doses reduce disease severity and result in higher yield. However, fungicides are costly to develop and when resistance arises, lowering the fungicide dose reduces the intensity of selection for resistance and can hence prolong fungicide utility. By relating yield to the cumulative amount of uninfected host tissue, we calculate

[1]Epidemiology and Modelling Group, Department of Plant Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EA, U.K. (e-mail: rjh78@hermes.cam.ac.uk).

[2]Veterinary Laboratories Agency, New Haw, Addlestone, Surrey KT15 3NB, U.K. (e-mail: S.Gubbins@vla.defra.gsi.gov.uk).

[3]Epidemiology and Modelling Group, Department of Plant Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EA, U.K. (e-mail: cag1@cus.cam.ac.uk).

optimal fungicide application strategies which balance these conflicting aims.

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