Effects of heterogeneity of crop fertilisation at the landscape scale in epidemics and pathogen evolution

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Abstract

Agroecology suggests that spatial heterogeneity can be a lever for crop protection. Using a model we study whether landscape-level heterogeneity in cultural practices can sustainably hamper crop pathogens epidemics. We focus on crop fertilisation in the wheat-leaf rust pathosystem. We use a spatially explicit model in which the agricultural landscape is a mosaic of individual fields, with either high or low crop fertilisation. Fertilisation determines crop growth dynamics and therefore resources available for epidemic development. Within each individual field, we use a SEIR epidemiological model. Fields are linked together through pathogen dispersal. We study the epidemiological and evolutionary dynamics of the pathogen in this context, concentrating on the latent period as the evolving trait.

Using methods from adaptive dynamics, we find that spatial heterogeneity is likely to induce pathogen maladaptation: the occurrence of pathogen strains that are significantly less competitive than the optimal strain in a given environment. When such maladaptation occurs, certain landscape configurations reduce the quantity of inoculum released into the landscape and slow down the colonization of the landscape by the pathogen. But we also demonstrate that these beneficial effects of spatial heterogeneity are not sustainable: after a period of maladaptation, pathogens may undergo a process of evolutionary branching, thereby filling all available resources niches in the landscape.

Even if resource heterogeneity at the landscape scale alone may not be sufficient to sustainably limit crop pathogen epidemics, it may prove useful in combination with other types of spatiotemporal heterogeneity that promote local pathogen maladaptation. These results further emphasize the need to take pathogen evolution into account when addressing questions about sustainability in agriculture, even for "soft" regulation methods such as fertilisation practices, as opposed to "hard" methods of pesticides and resistance.

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