Investigating spatiotemporal strategies to deploy resistance genes in canola

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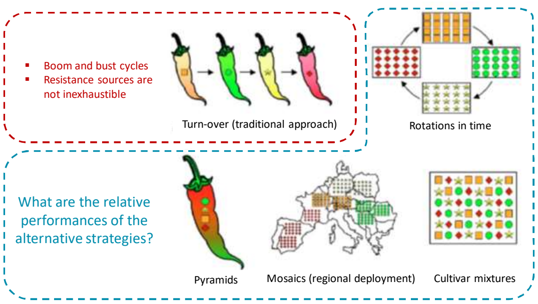
Resistance is useful, but not eternal

Pathogen	References with examples of low resistance durability
Fungi (incl. blackleg)	Johnson R (1983). p5-26 in: Durable Resistance in Crops, Springer.
	Stuthman DD, Leonard KJ and Miller-Garvin J (2007). p319-367 in: Advances in Agronomy, Academic Press.
	Brown JKM (2015). *Annu. Rev. Phytopathol*. 53:513-539.
	Parlevliet JE (2002). *Euphytica* 124:147-156.
	McDonald BA & Linde C (2002). *Annu. Rev. Phytopathol.* 40:349-379.
	Burdon JJ, Barrett LG, Rebetzke G and Thrall PH (2014). *Evol. Appl*. 7:609-624.
	Rouxel T, et al. (2003) *Eur. J. Plant Pathol.* 109:871-881
	Brun H et al. (2010). *New Phytol.* 185:285-299.
	Sprague S et al. (2006). *Eur. J. Plant Pathol.* 114:33-40
	Sprague S et al. (2006). *Plant Dis.* 90:190-198
	Van de Wouw AP et al. (2014). *Field Crops Res.* 116:114-151
	Van de Wouw AP, Marcroft SJ and Howlett BJ (2016). *Crop and Pasture Science* 67:273-283.
Oomycetes	Stuthman DD, Leonard KJ and Miller-Garvin J (2007). p319-367 in: Advances in Agronomy, Academic Press.
	Burdon JJ, Barrett LG, Rebetzke G and Thrall PH (2014). *Evol. Appl*. 7:609-624.
	McDonald BA & Linde C (2002). *Annu. Rev. Phytopathol*. 40:349-379.
	Parlevliet JE (2002). *Euphytica* 124:147-156.
Bacteria	McDonald BA & Linde C (2002). *Annu. Rev. Phytopathol*. 40:349-379.
	Parlevliet JE (2002). *Euphytica* 124:147-156.
Viruses	Janzac B, Fabre F, Palloix A and Moury B (2009). *Molec. Plant Pathol*. 10:599-610.
	García-Arenal F & McDonald BA (2003). *Phytopathology* 93:941-952.
	Parlevliet JE (2002). *Euphytica* 124:147-156.
	Brown JKM (2015). *Annu. Rev. Phytopathol*. 53:513-539.
	Lecoq H, Moury B, Desbiez C, Palloix A and Pitrat M (2004). *Virus Res*. 100:31-39.
Nematodes	McDonald BA & Linde C (2002). *Annu. Rev. Phytopathol*. 40:349-379.
	Djian-Caporalino C et al. (2014). *BMC Plant Biol*. 14:1-13.

Alternative strategies to deploy plant resistance



McDonald & Linde (2002). Annu. Rev. Phytopathol. 40:349-379

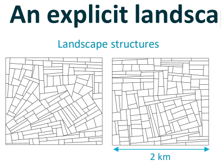
- What is the optimal strategy to deploy plant resistance?
- What is the impact of the type of resistance?
- What is the impact of landscape organisation?
- What is the impact of the pathosystem considered?

Development of a general spatiotemporal stochastic simulation model

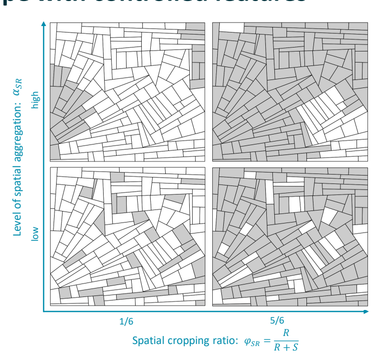
R package landsepi

Rimbaud L, Papaix J, Rey J-F, Barrett LG and Thrall PH (in press).
Assessing the durability and efficiency of landscape-based strategies to deploy plant resistance to pathogens. *PLoS Comput. Biol.*

An explicit landscape with controlled features



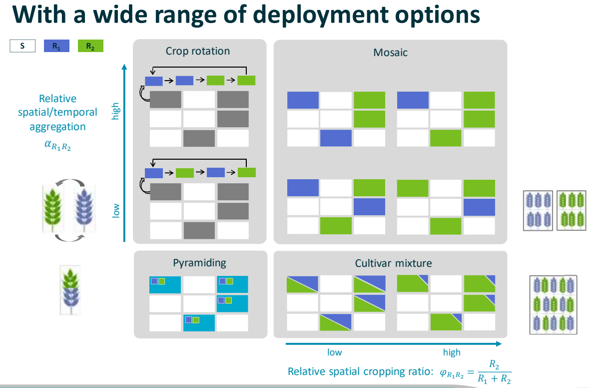
1. Generation of landscape structures using a T-tessellation algorithm
2. Allocation of different cultivars in controlled proportions and spatial aggregation



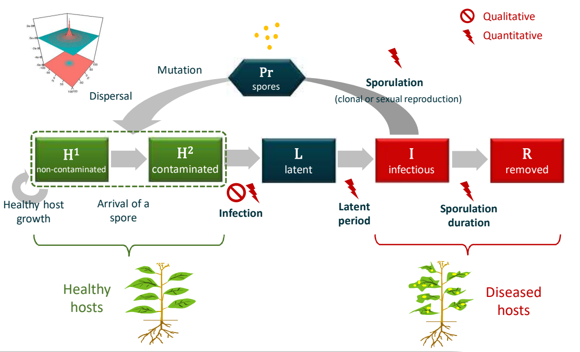
Fields with susceptible cultivar (S)
➡ Pathogen initially present

Fields where resistance is deployed (R)
➡ What is the best deployment strategy?

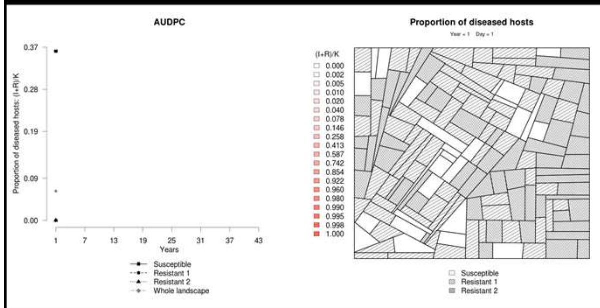
With a wide range of deployment options



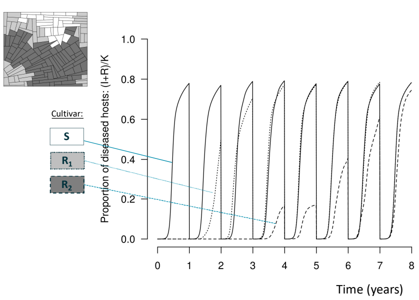
Host response to disease



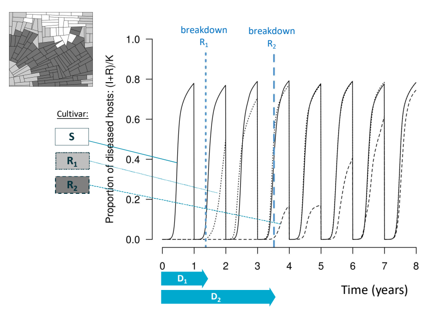
Simulated example: mosaic of two major genes



Model outputs: evaluation criteria



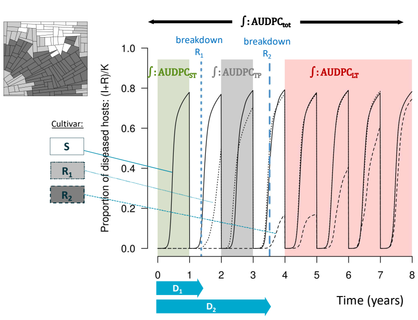
Model outputs: evaluation criteria



Evolutionary outcome:

Durability R_1
Durability R_2
Time to super-pathogen emergence

Model outputs: evaluation criteria



Epidemiological outcome:

Short-term control
Control during transitory period
Long-term control
Gobal efficiency

Evolutionary outcome:

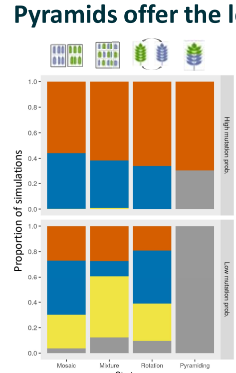
Durability R_1
Durability R_2
Time to super-pathogen emergence

SIMULATED SCENARIO

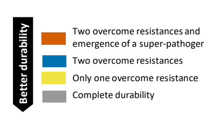
Rusts of cereal crops

- clonal reproduction
- 2 major R genes conferring immunity

Pyramids offer the longest durability…



Under our model assumptions, pyramiding 2 major resistance genes is the strategy less likely to breakdown, regardless the mutation probability

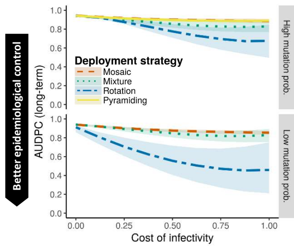


SIMULATED SCENARIO

Rusts of cereal crops

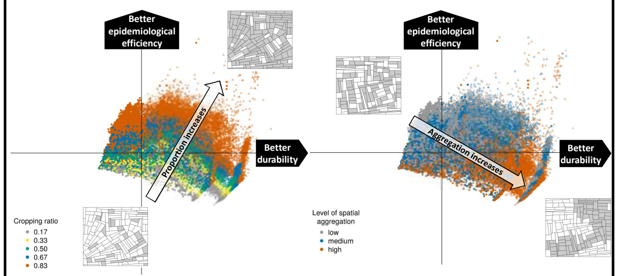
- clonal reproduction
- 2 major R genes conferring immunity

…but rotations better mitigate epidemic losses



When some or all sources of resistance have broken down, rotation of resistant cultivars becomes the best option, especially if mutation triggers high fitness costs.

Contrasting effects of landscape organisation



Epidemiological and evolutionary control are not always correlated

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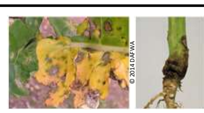
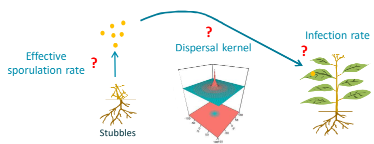
What's next?
Simulating canola blackleg



- Few available resistant cultivars
- Strong adaptation potential of *Leptosphaeria maculans*

→ The general model (R package *landsepi*) can serve as a tool to evaluate different deployment strategies

→ We are currently parameterising the model to specifically simulate canola blackleg



- High contribution of sexual ascospores from stubbles to epidemics

→ Reasortment of genes may considerably impact longevity of pyramids!

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Thank you

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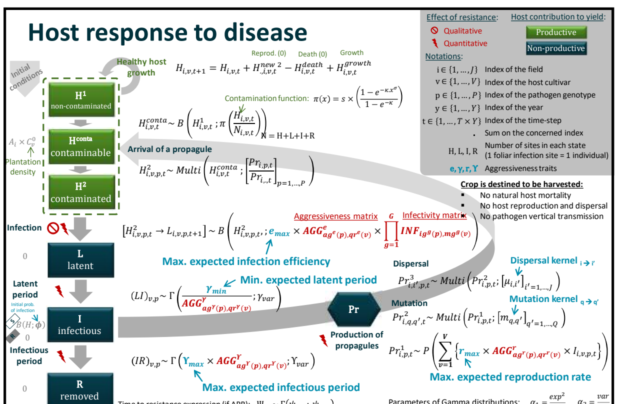
Host response to disease



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