Durable plant disease resistance by evolution management - how?

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SEVENTH FRAMEWORK PROGRAMME

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Innovative crop protection for sustainable agriculture

IPM

Background:

- Environmental effects of pesticides
- Withdrawal of active compounds
- Resistance development

Need to do more with cultural methods & genetic resistance

But resistance can also be broken.

Optimal usage of scarce resistance genes

- Placement in cultivars
- Placement in landscape
- Placement in time

Questions

- What is the effect on durability of resistance genes of:
  - Gene stacking
  - Diversified use of genes in environment
  - Sequential usage of different resistance in time
  - Hybrid strategies of the above three
  - Rotational strategies
  - Clustering and spatial separation of host fields

Model approach - system

- Host: wheat (*Triticum aestivum*)
- Pathogen: *Puccinia striiformis*

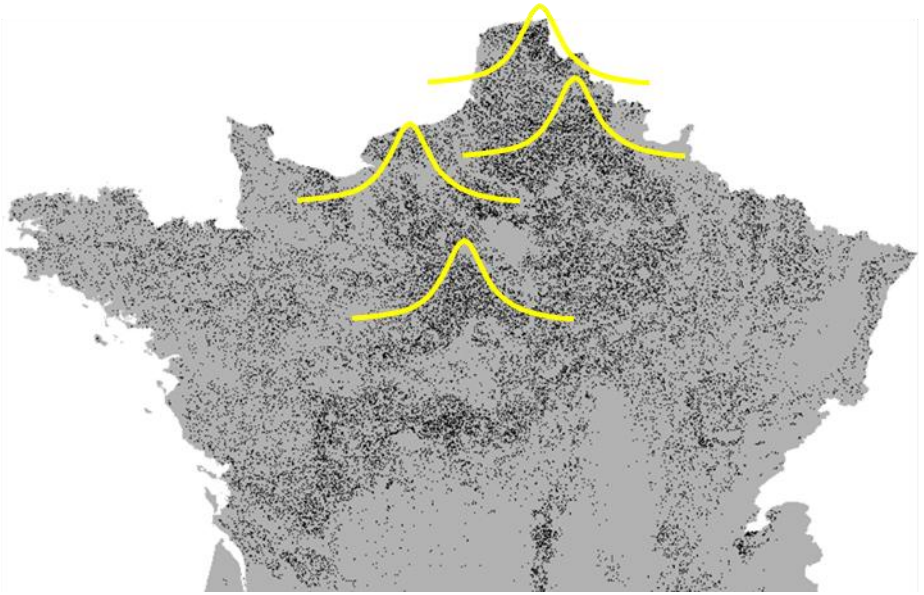
- Mixture of fields
  - Host and non-host fields
  - Fraction of host are resistant fields

- Pathogen population
  - Fraction is virulent
  - Fraction is avirulent

Model approach – Dispersal

- Fraction of spores leave the field
- Dispersal kernel with fat tails

  → long distance dispersal

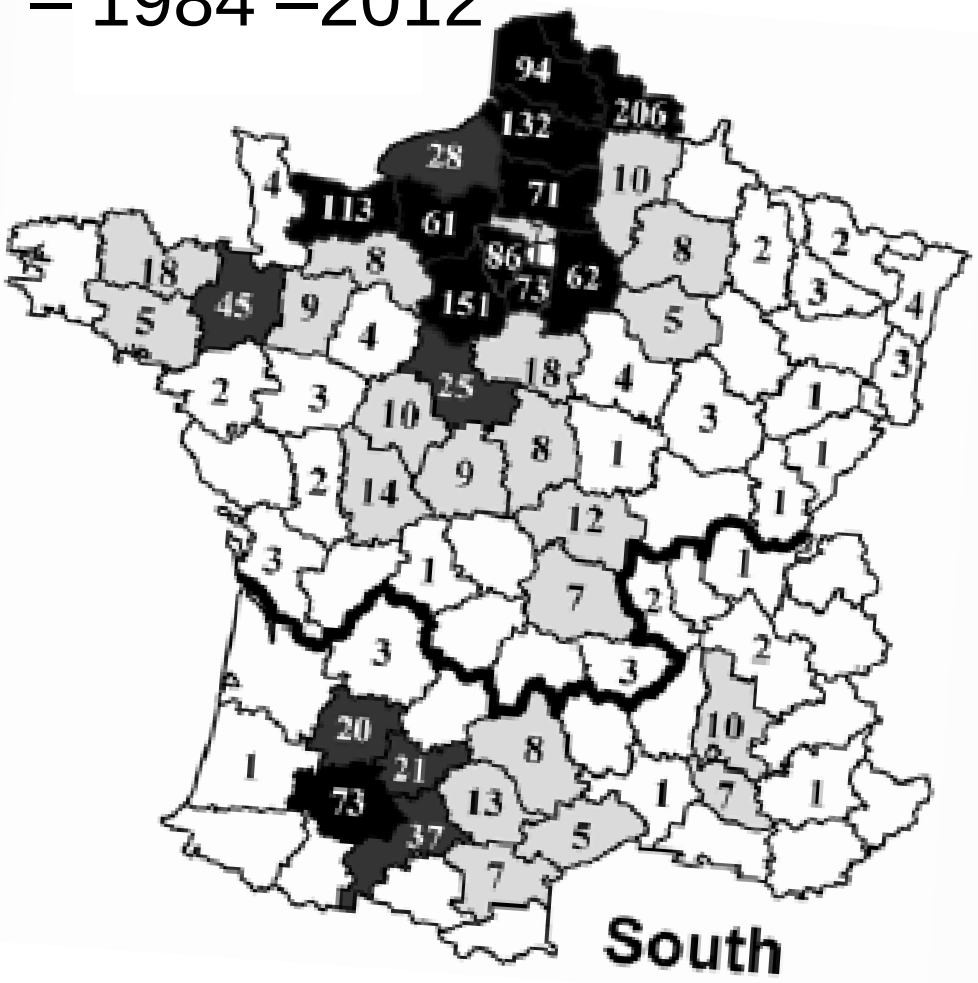


Mutation & selection

- Selection scenarios
  - resistance breaking genotypes initially present
- Mutation and selection scenarios
  - virulence has first to emerge by mutation, and is subsequently selected

Landscape - France

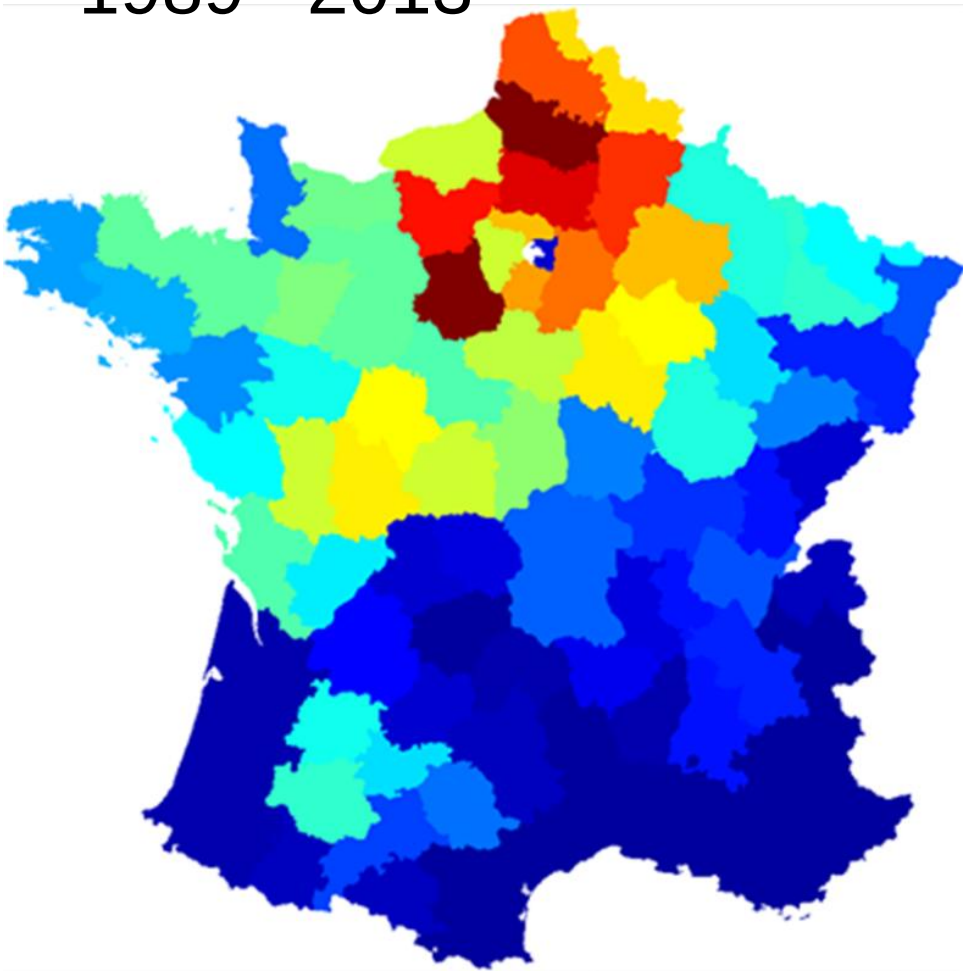
- Yellow rust data
  - 1984 –2012



de Vallavieille-Pope et al., 2012

Landscape - France

- % wheat per department
  - 1989 –2013

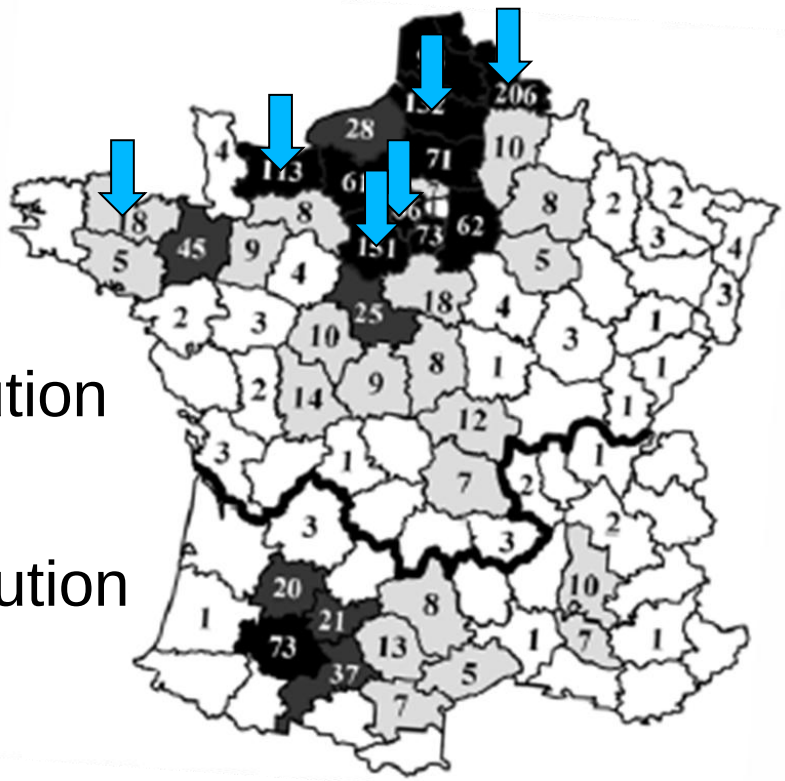


Landscape - France

- Arable land
  - Corine land cover raster data

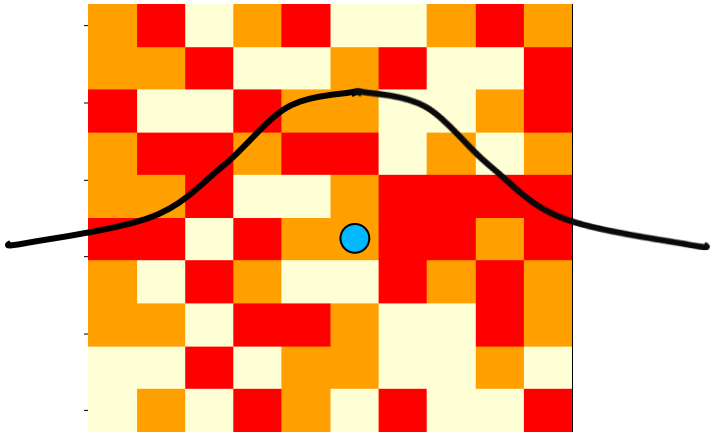
Simulation set-up

- Initial pathogen population (year 1)
  - 6 departments North-west France:
    - Nord, Somme, Calvados, Yvelines, Eure-et-Loir and Côtes d'Armor
  - 300 susceptible fields
    - Randomly selected
  - Selection scenario
    - Homogeneous distribution
  - Mutation scenario
    - Heterogeneous distribution



Simulation set-up

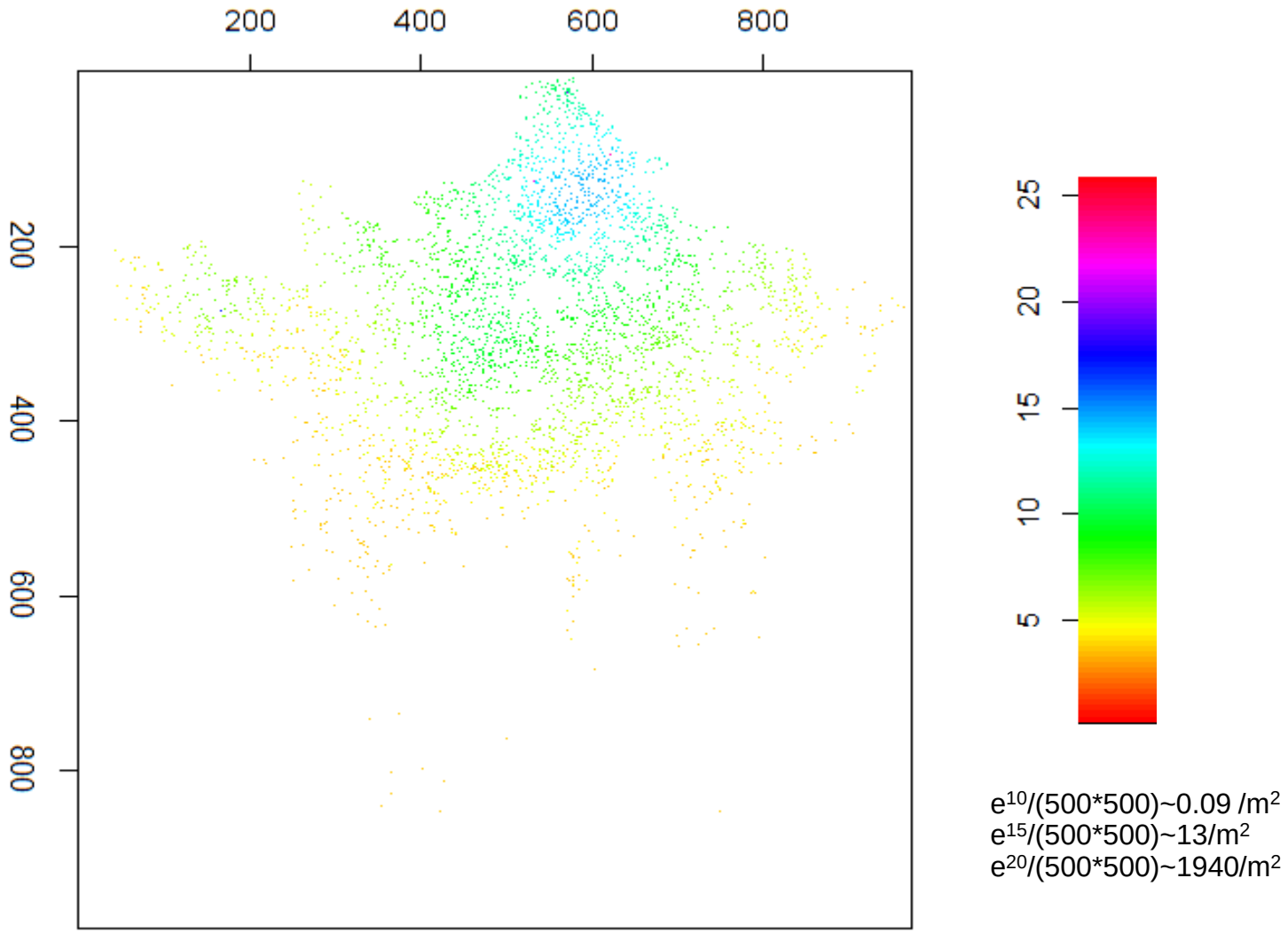
- 30 growing seasons
- 6 pathogen generations/year
- Within each pathogen population
  - Dispersal of spores
  - Selection (carrying capacity)
  - Reproduction
  - (Mutation)
- Between growing seasons
  - local survival in departments Northwest coast



Scenario testing – deployment strategies

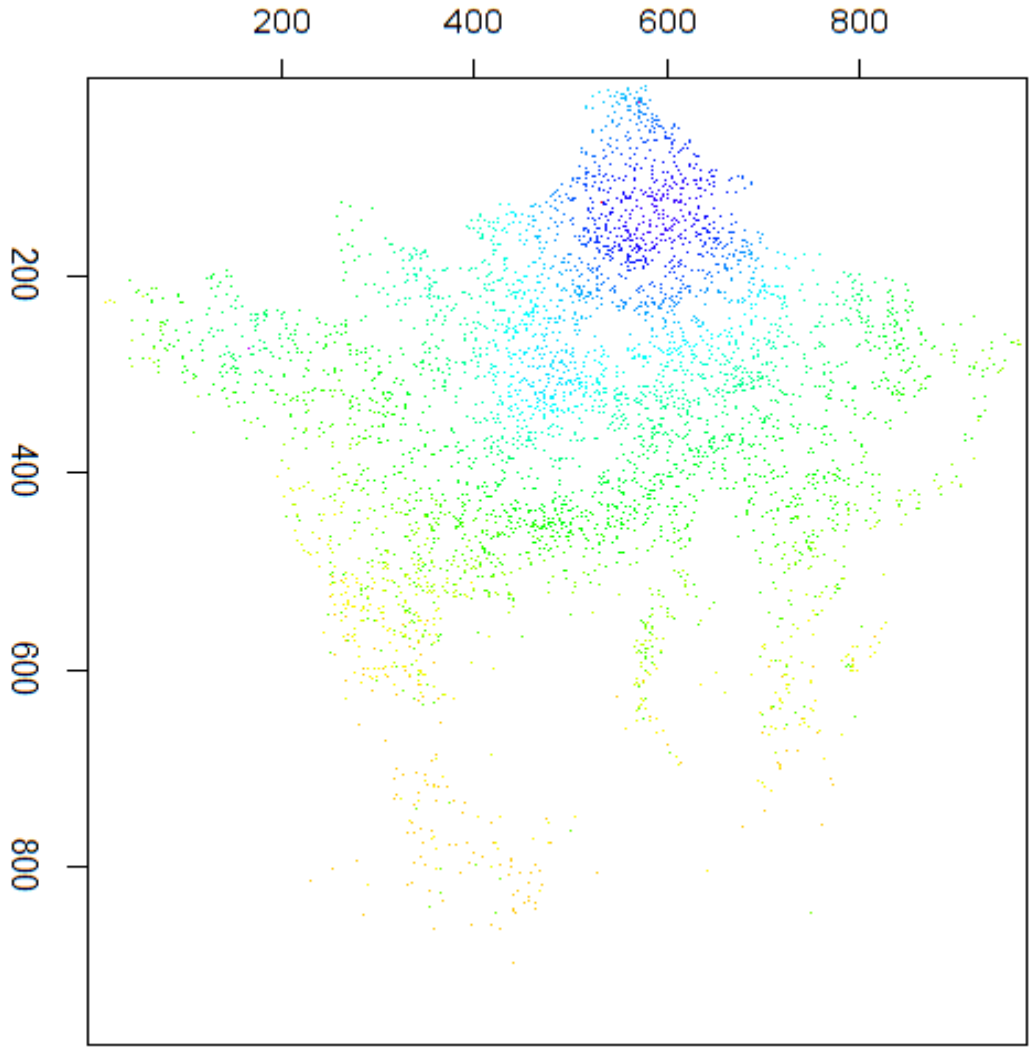
- Variety choice
  - Sequential use
  - Pyramiding
  - Concurrent use of single-gene and double-gene resistant varieties
  - Simultaneous use of 2 (or 4) single-gene resistant varieties
- Crop rotation
  - 1year wheat followed by 2 years other crop
- Selection vs mutation

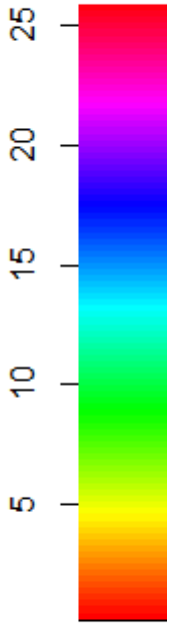
Results – spatial dynamics A(1)



$e^{10}/(500*500) \sim 0.09\ /m^2$
$e^{15}/(500*500) \sim 13/m^2$
$e^{20}/(500*500) \sim 1940/m^2$

Results – spatial dynamics A(2)





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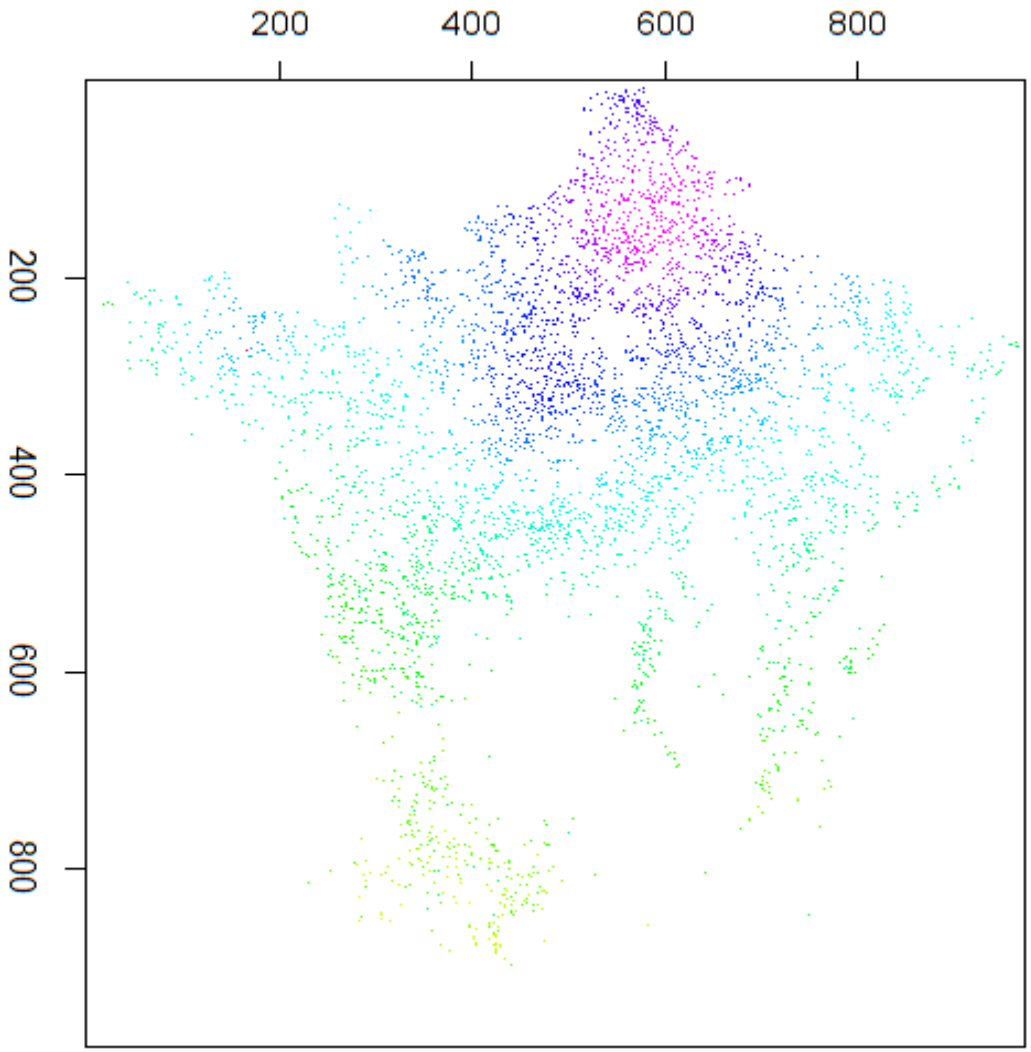
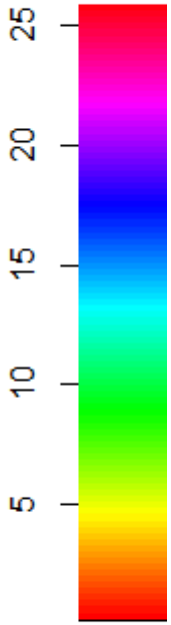
Results – spatial dynamics A(3)





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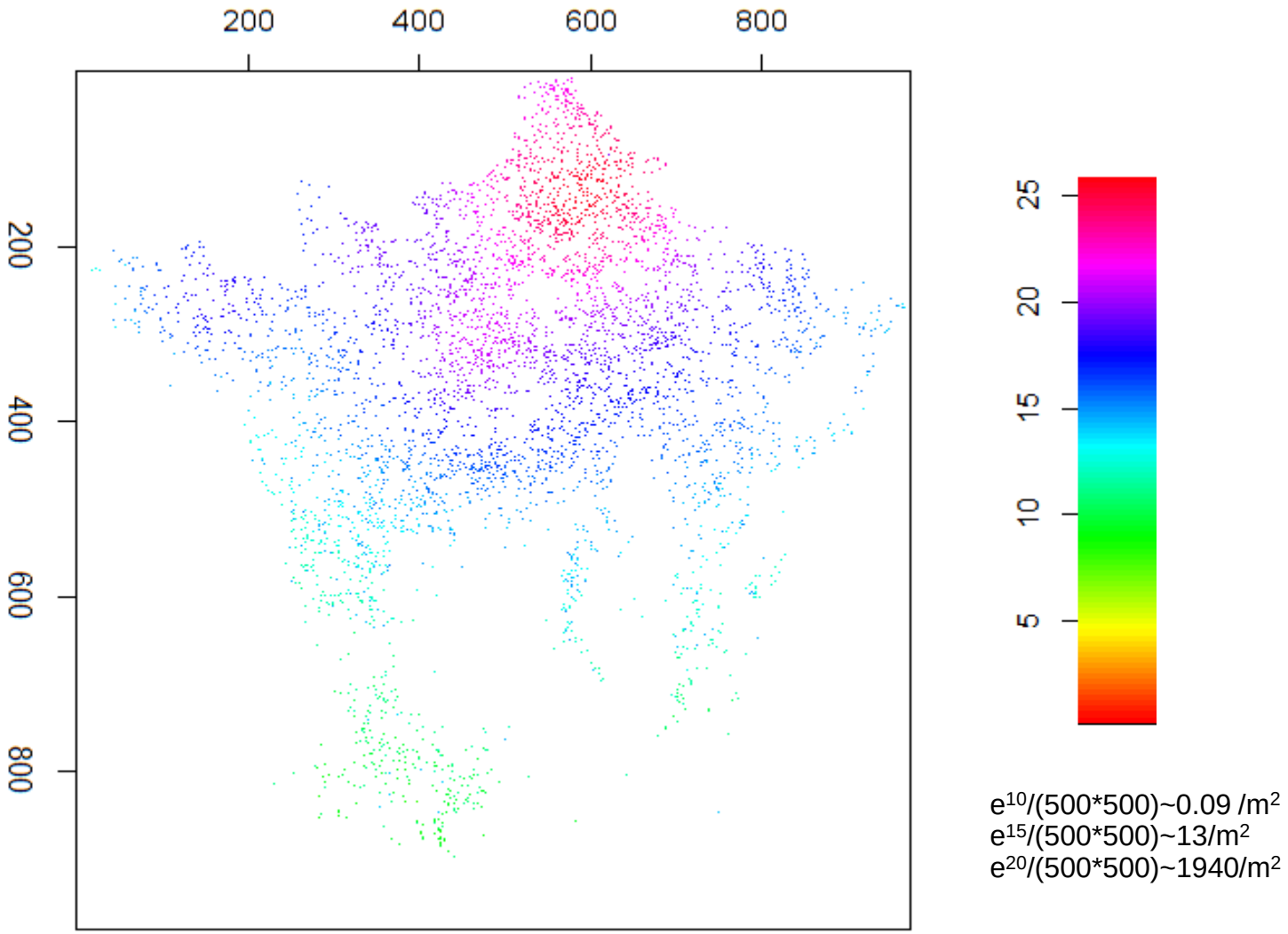
Results – spatial dynamics A(4)



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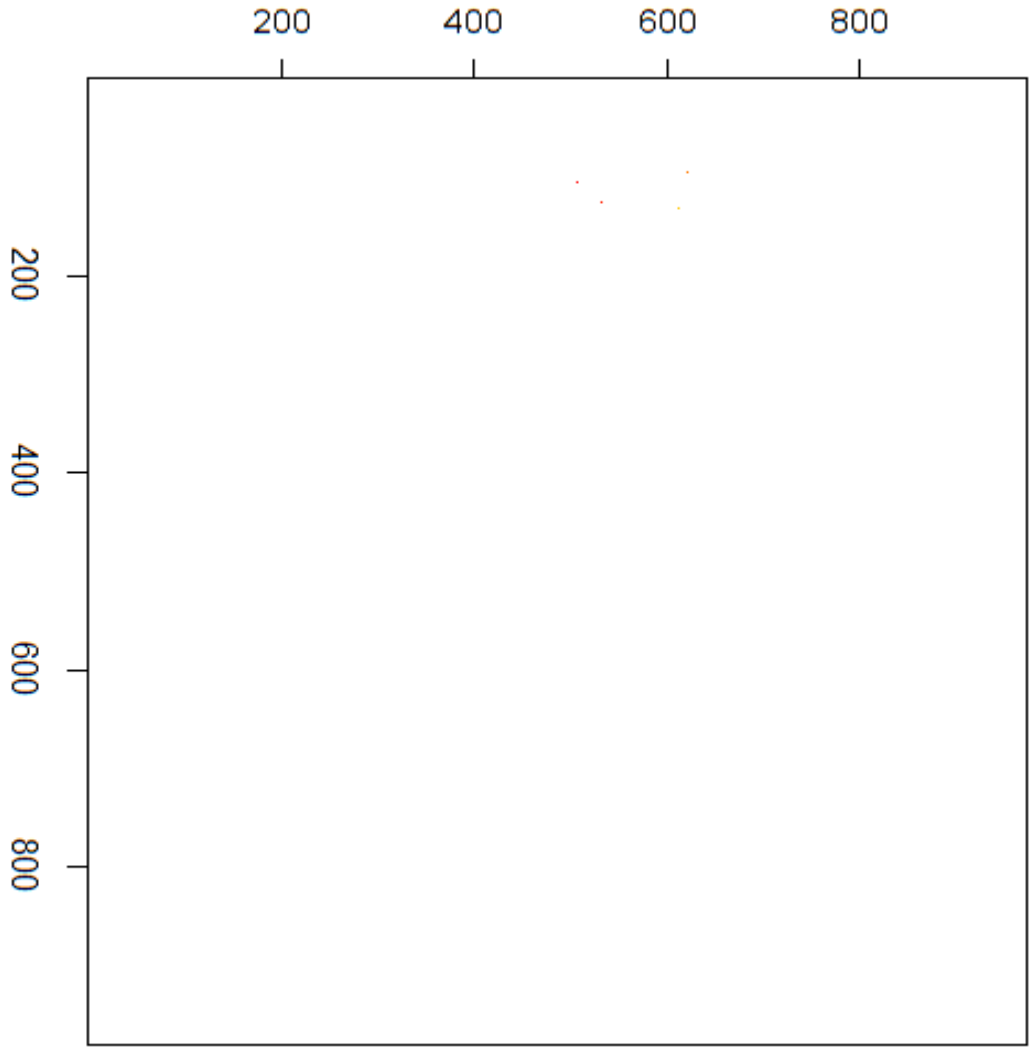
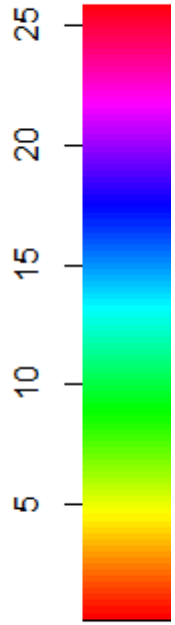
Results – spatial dynamics V(1)





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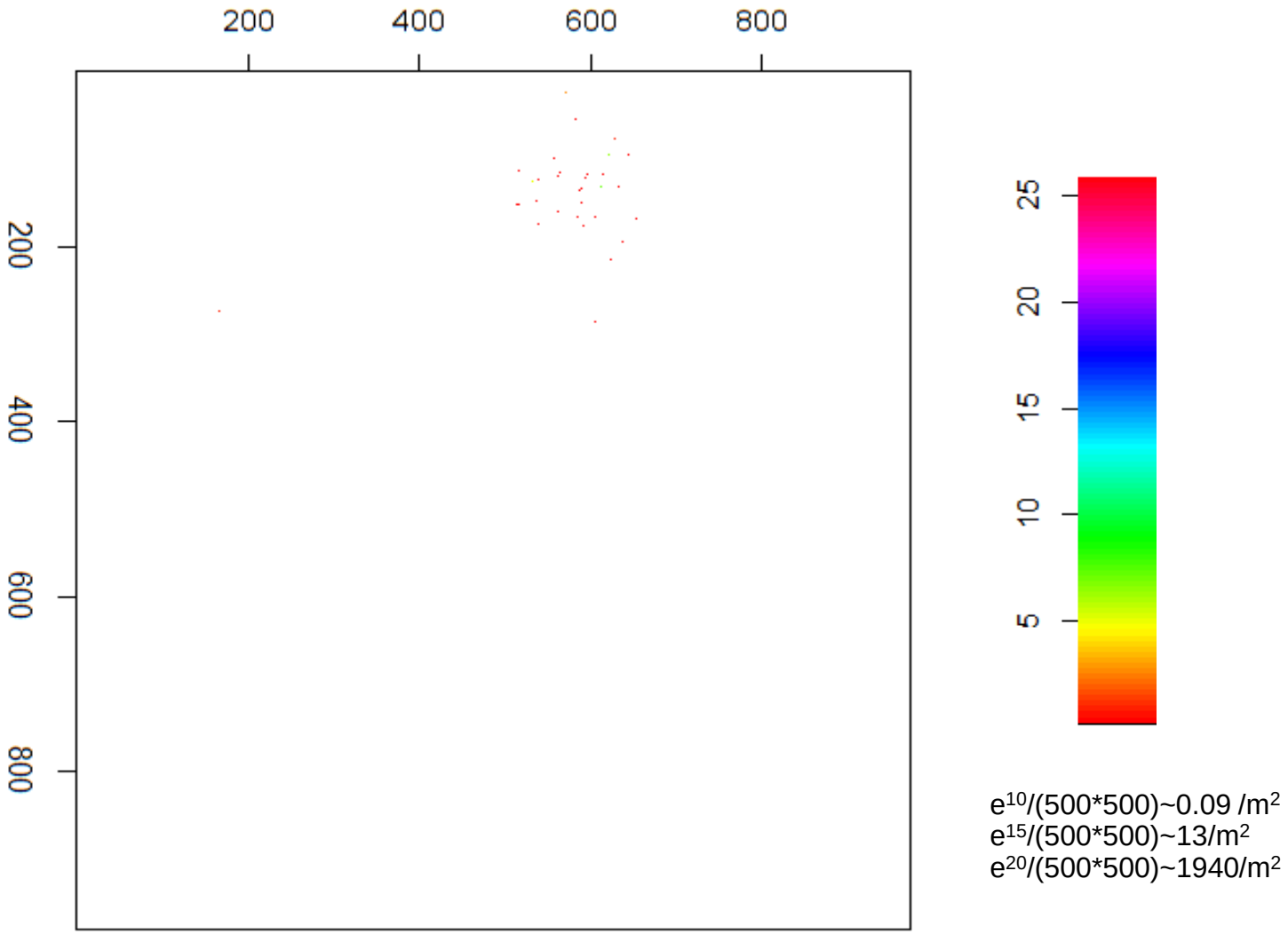

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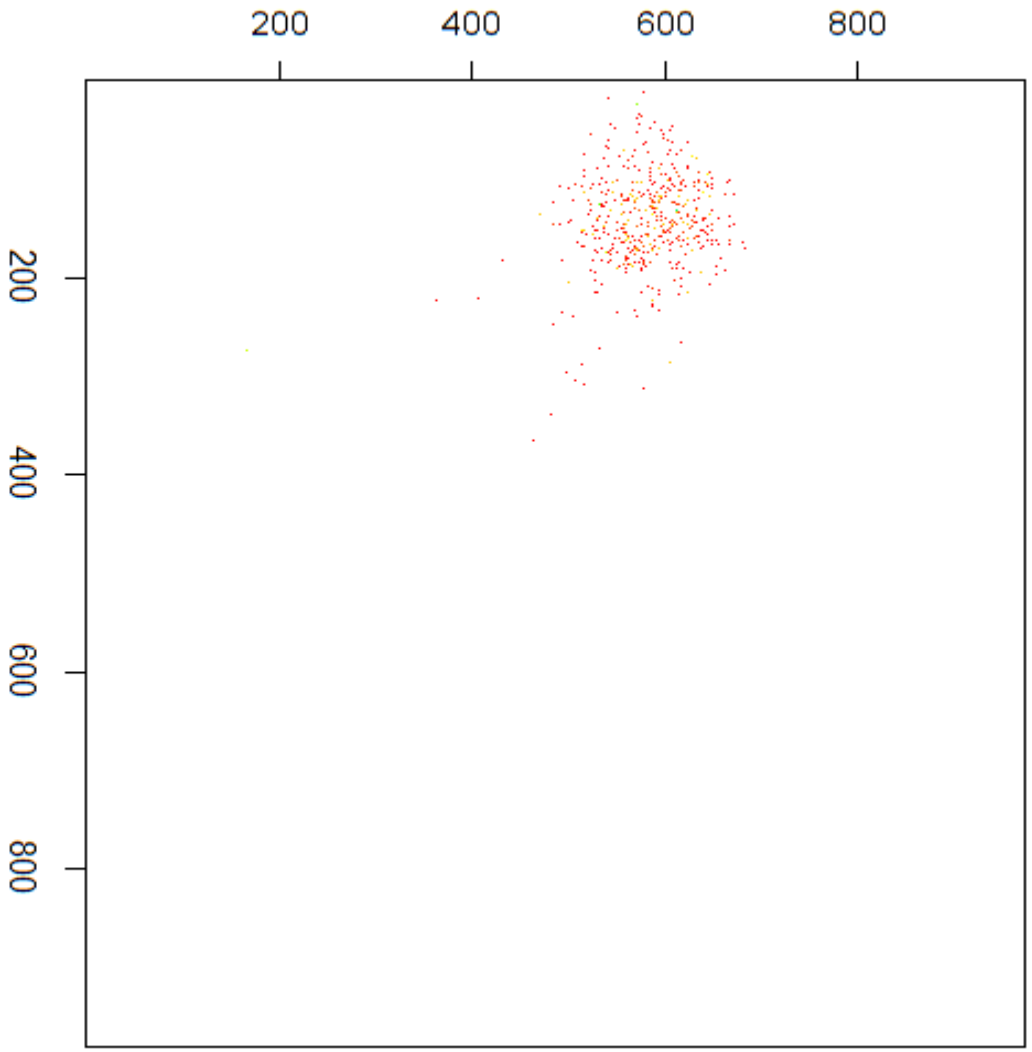

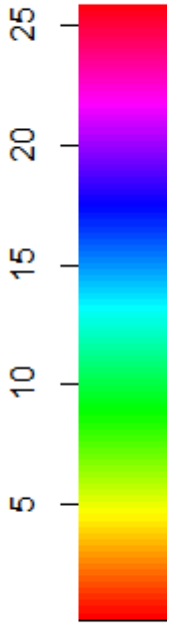

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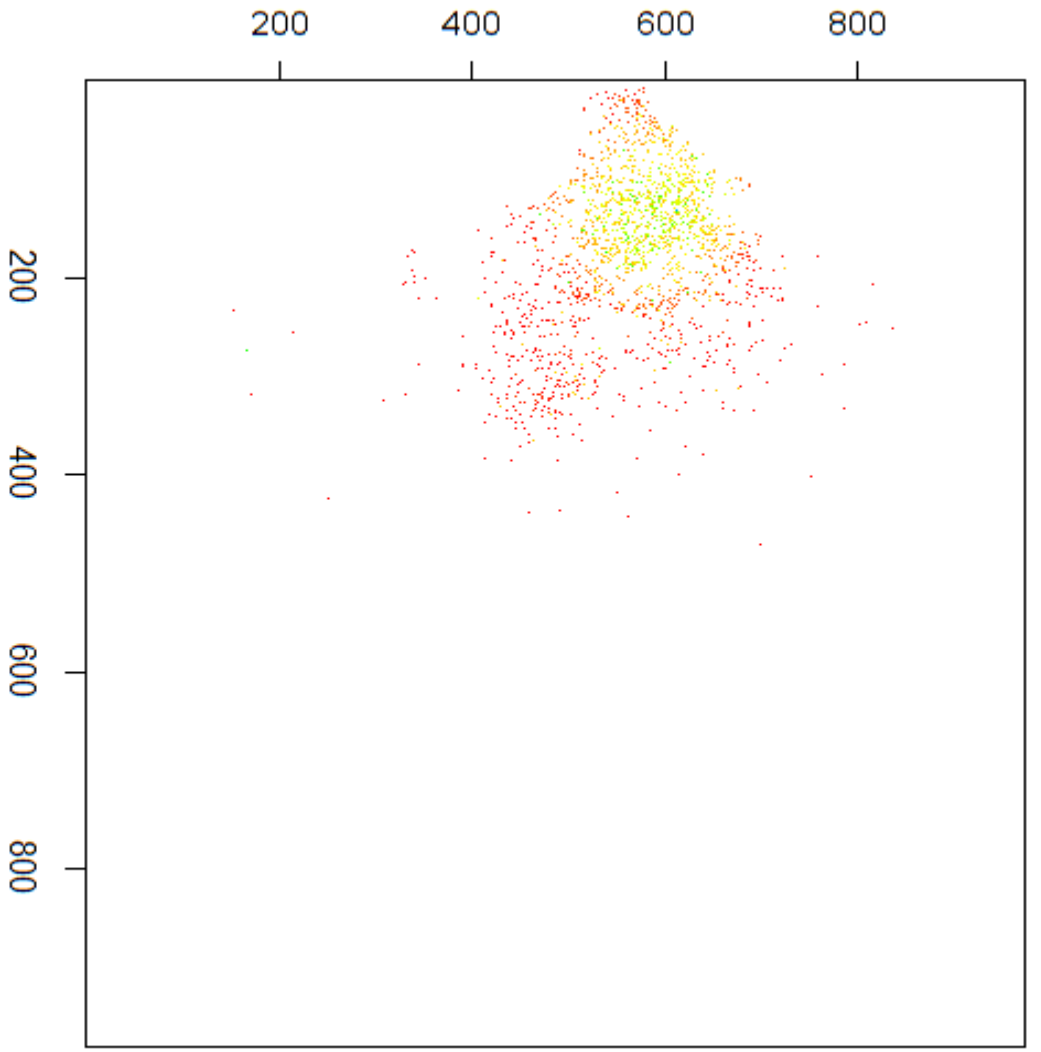
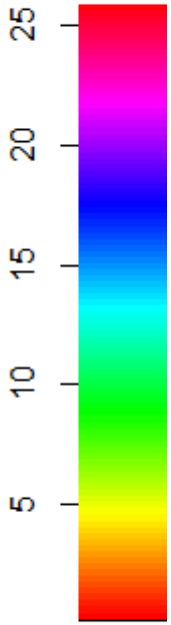
Results – spatial dynamics V(4)





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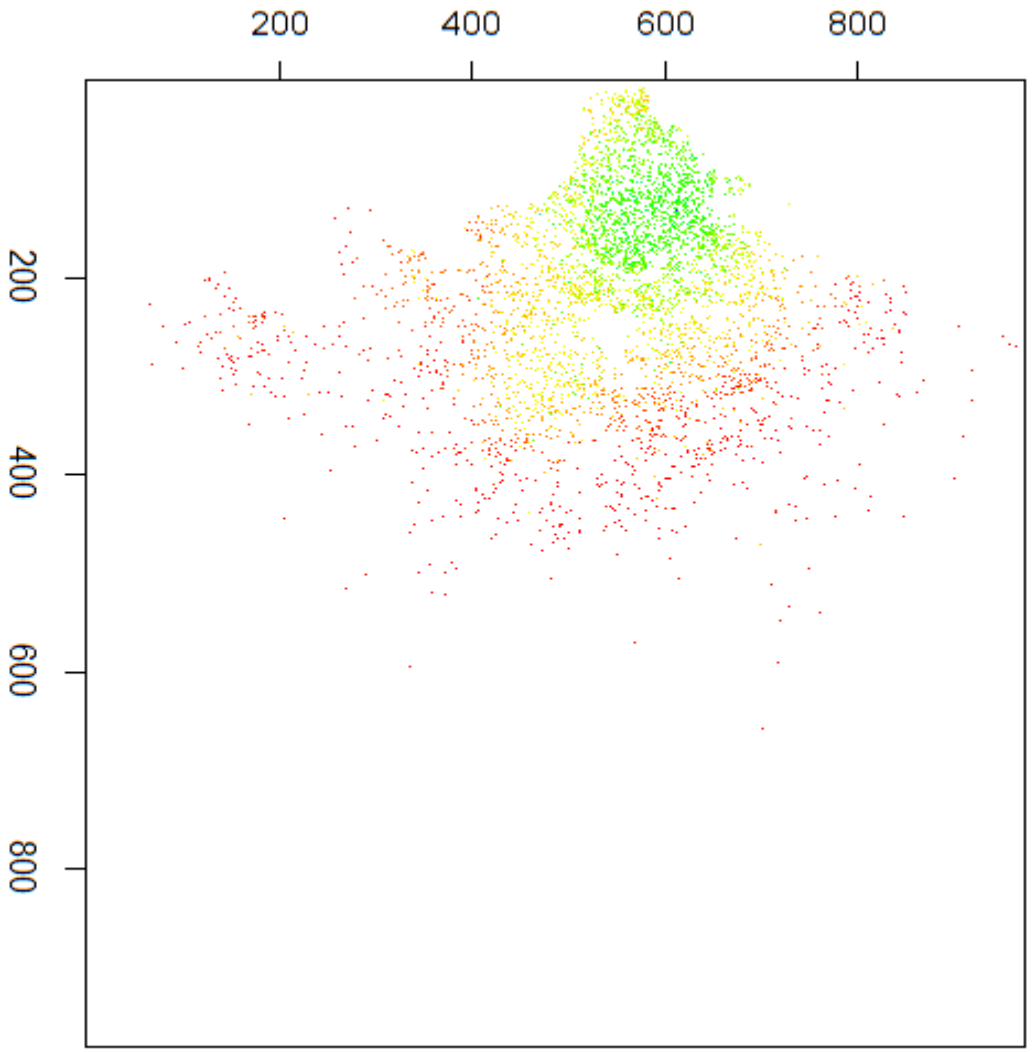
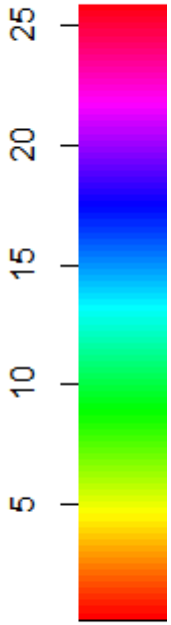
Results – spatial dynamics V(5)





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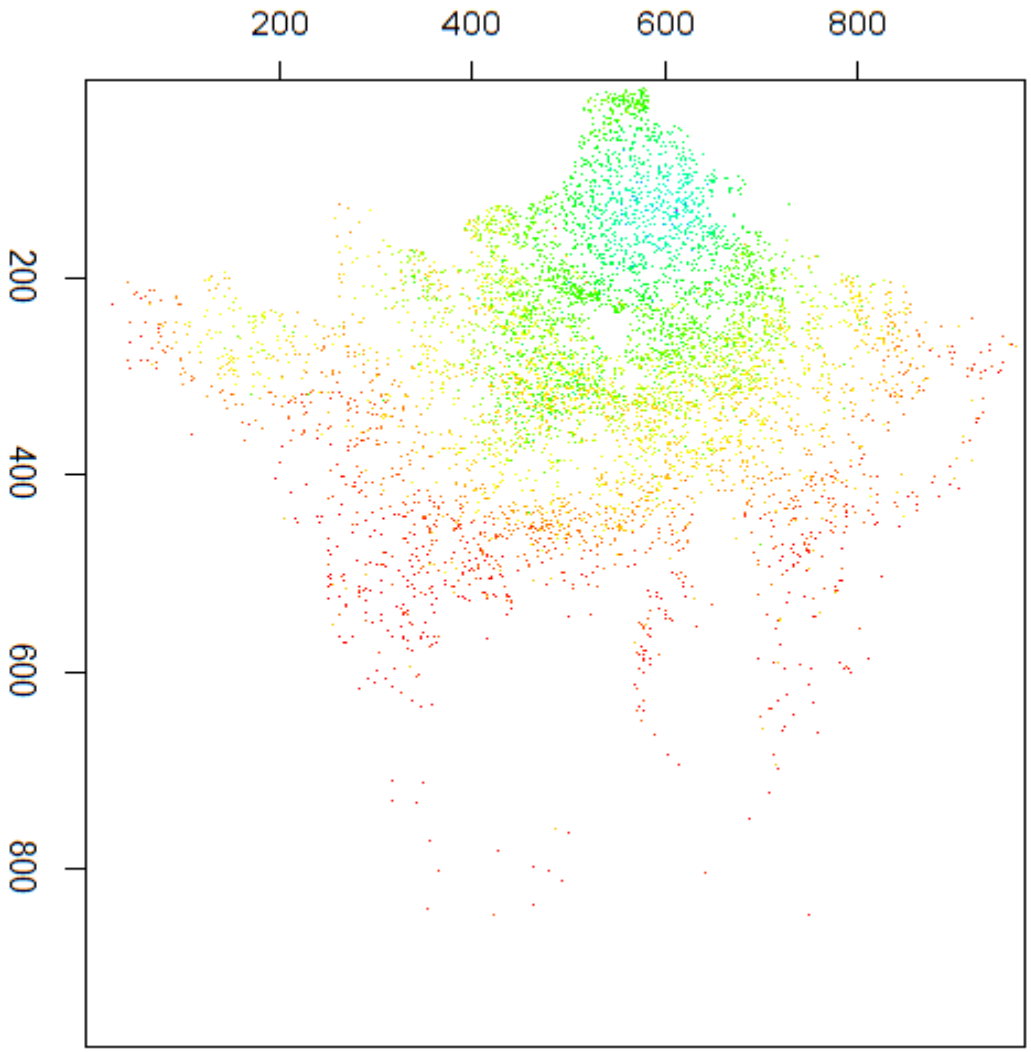
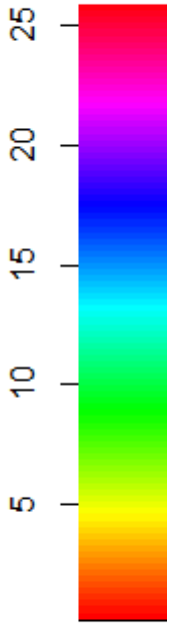
Results – spatial dynamics V(6)





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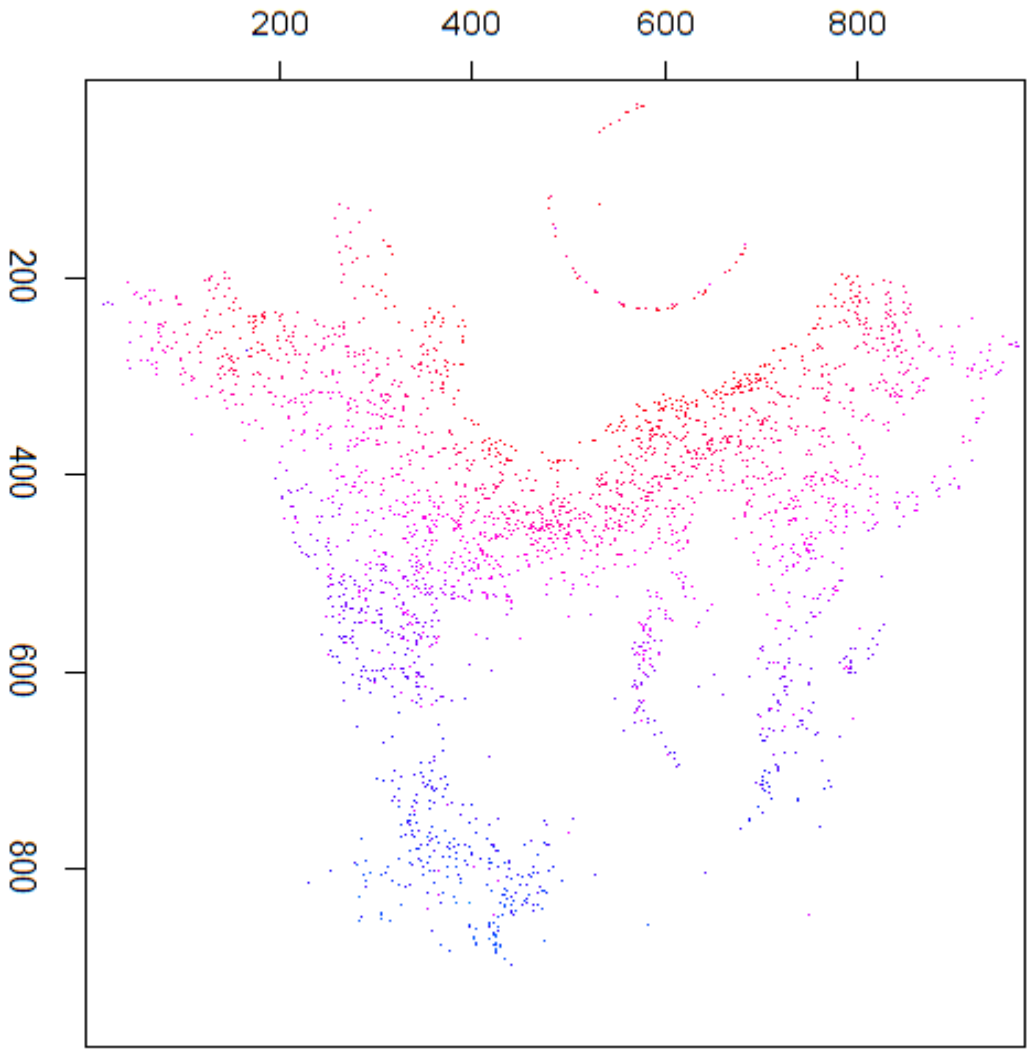
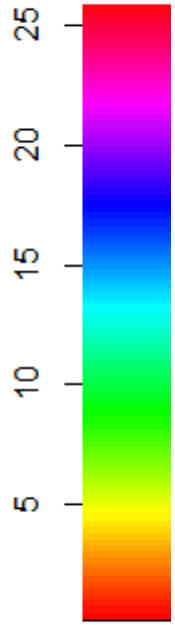
Results – spatial dynamics (A6)





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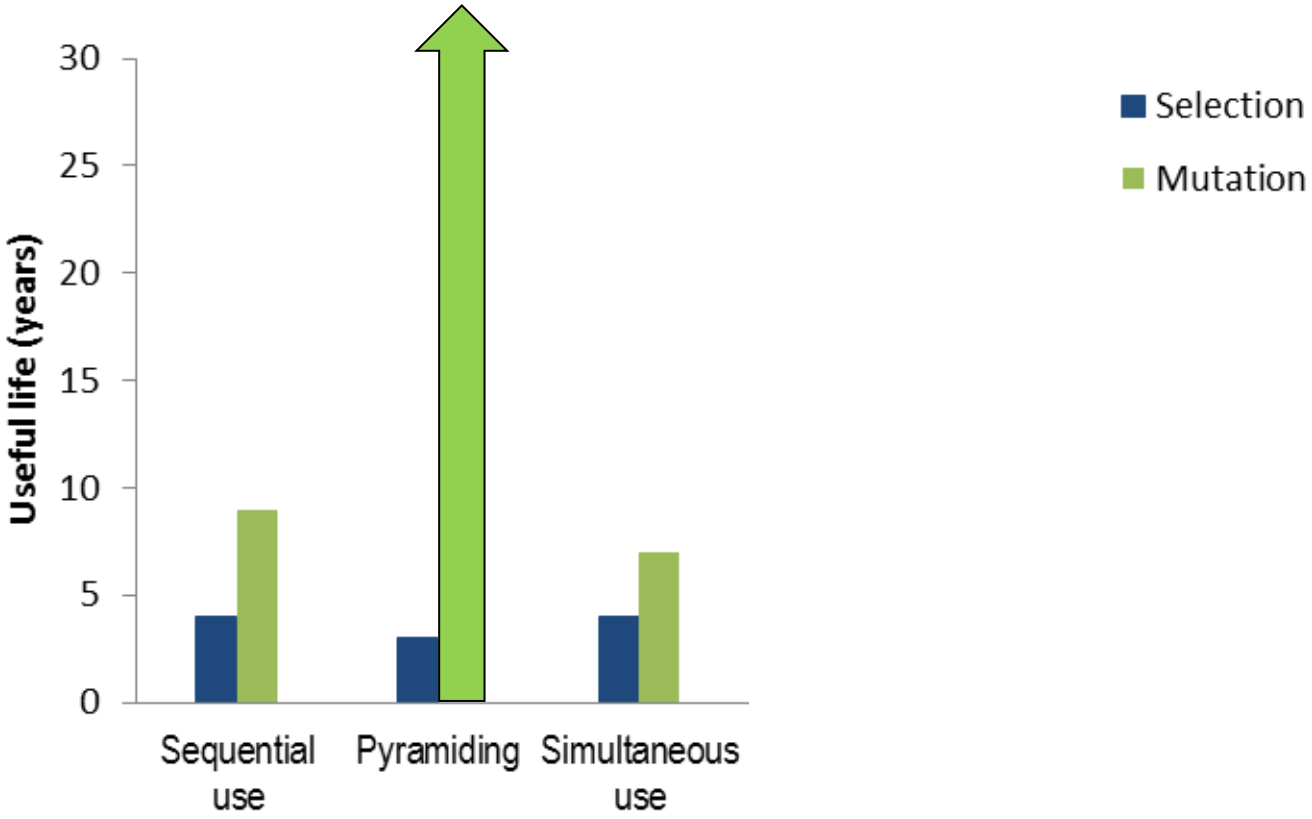
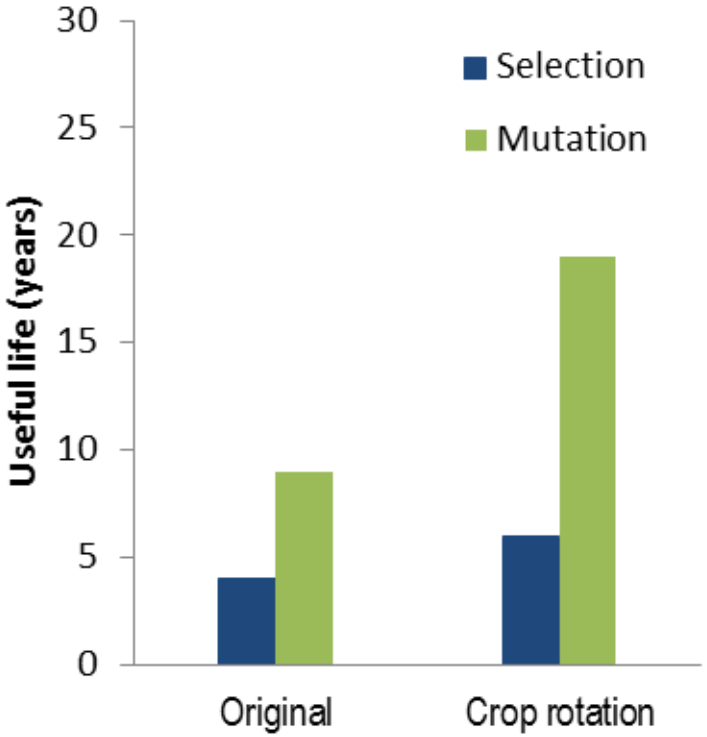
Results – useful life



- Pyramid of two resistance genes did not break down
- Simultaneous use decreases the useful life as compared to sequential use
- Concurrent use breaks down the resistance of the pyramid

Results – crop rotation (sequential use)



- Crop rotation prolongs useful life
- Strongest increase when virulence has to emerge by mutation
- Minor increase when virulence is already present
- Positive effect even stronger for simultaneous growth

Conclusions on useful life

- When virulence is already present
  - Differences are small
- When virulence has to emerge by mutation
  - Useful life was highest for pyramiding
  - Concurrent use reduces useful life of pyramid
- Crop rotation can prolong useful life

Thank you for your attention

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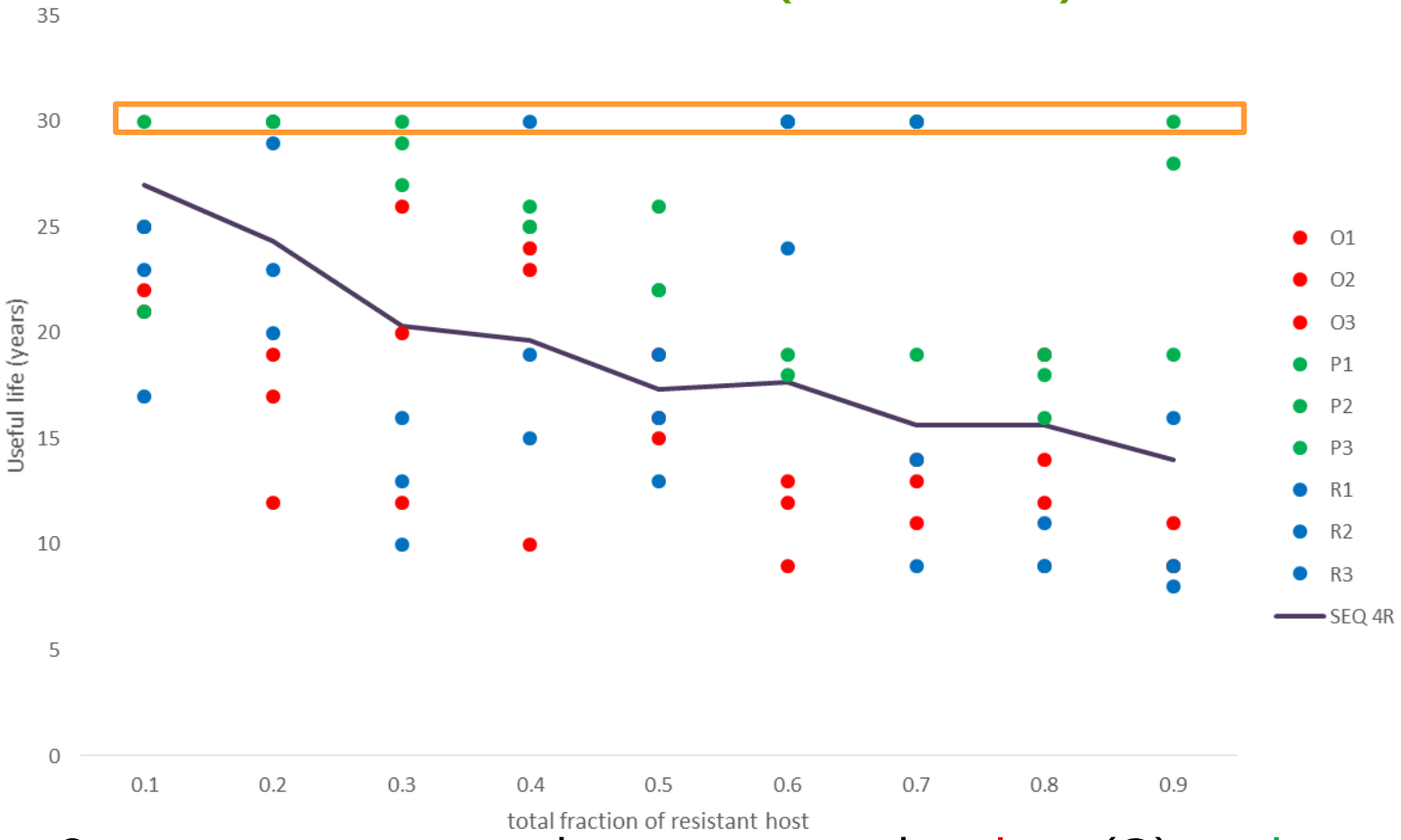
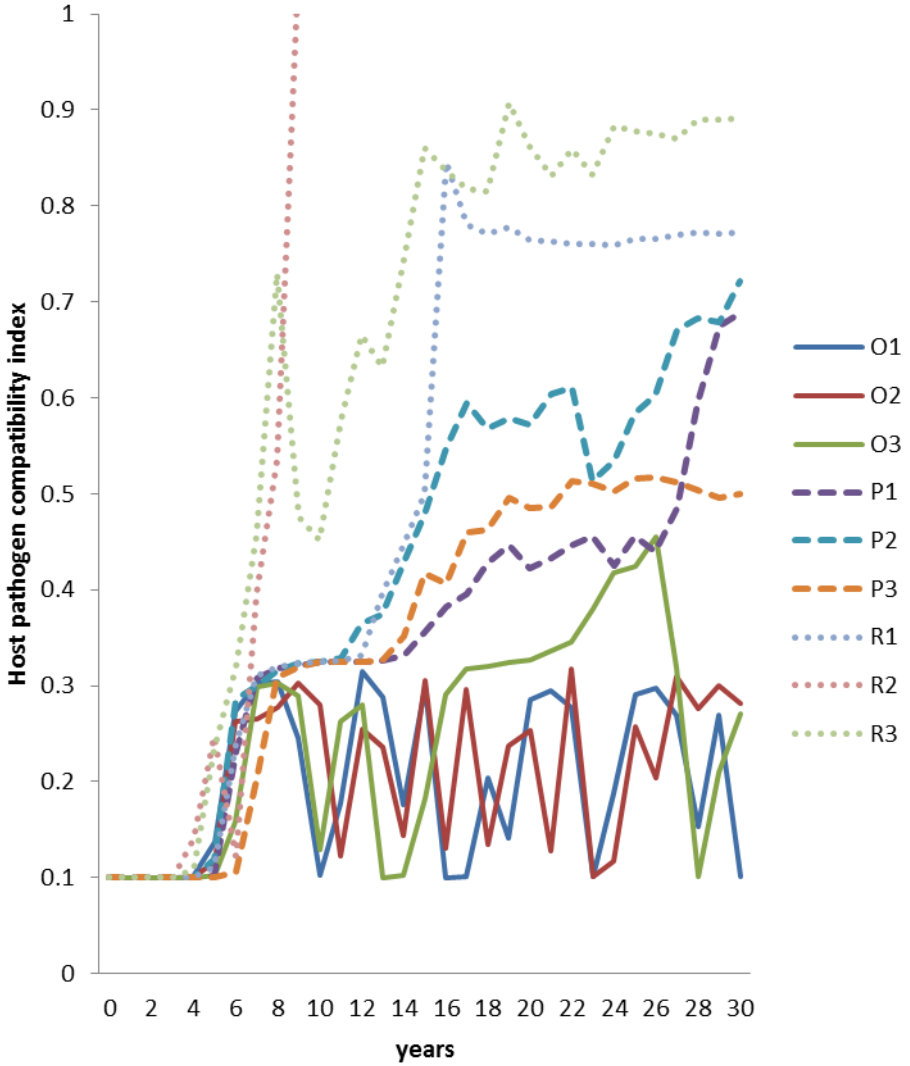
Results – 4 varieties (mutation)



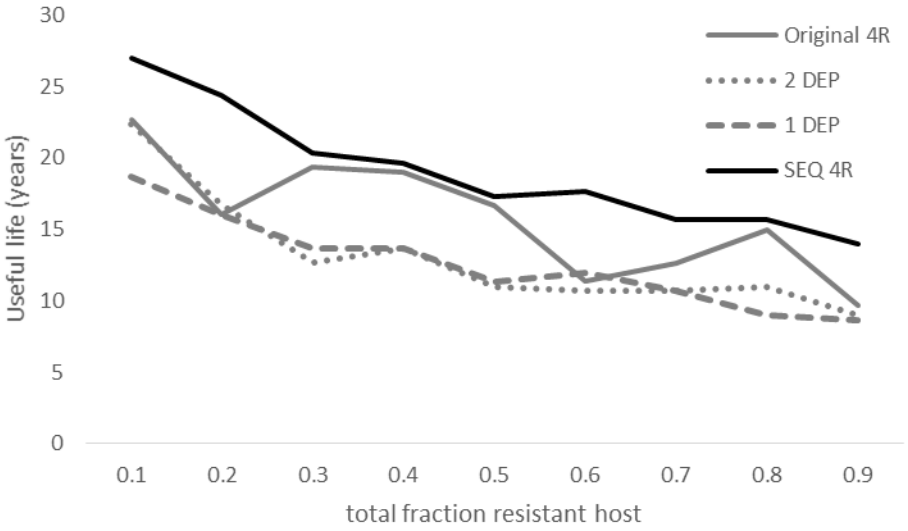
- 3 management strategies: remove and replace (O), prolong use (P) & remove and reallocate (R)
- Useful life highest for prolongation of use of a variety with broken down resistance

Results – 4 varieties

- 3 management strategies
  - replace (O, solid)
  - prolong (P, dashed)
  - reallocate (R, dotted)
- Useful life highest for prolongation of use of a variety with broken down resistance
- Slower increase in host-pathogen compatibility for prolongation
- Compatibility for replace stay lowest because of newly introduced varieties



Results – 4 varieties – spatial pattern



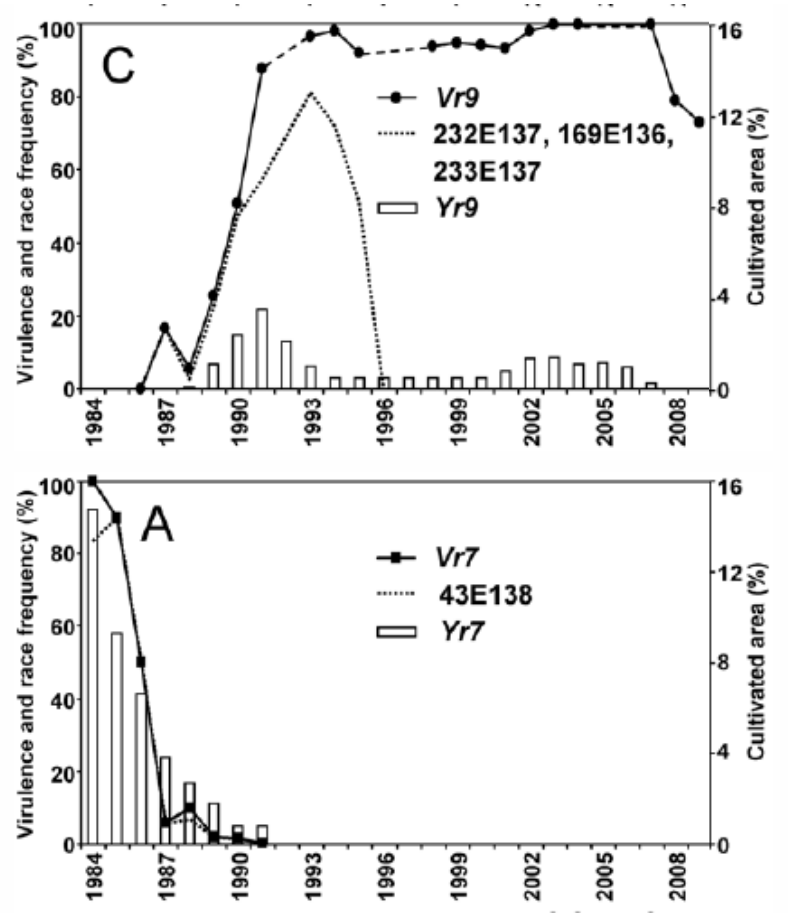
- Useful life simultaneous growth < sequential use for 4 resistance genes
- Useful life simultaneous growth very variable for mixed deployment
- Large scale spatial pattern reduces useful life
  - Smaller variation (always low useful life)

Model approach

- Carrying capacity
  - Field 500x500m with LAI of 5 →1250000 mm^2 lesions
  - Size lesion 70-90 mm^2 (Milus et al., 2009)
  - 80 mm^2 gives K~1.5 10^{11}

Discussion

- Sustainability = using existing resistance wisely
  - Remove and recycle genes



de Vallavieille-Pope et al., 2012