Department for Environment Food & Rural Affairs

ADAS





Integrated Pest Management: Science and Practice
Disease control in cereals

Neil Paveley and Frank van den Bosch

A video series funded by Defra and produced by ADAS

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How to manage pathogen virulence?

Aggressiveness: faster epidemics and/or ability to cause disease in a wider range of conditions

Virulence: overcoming specific disease resistance genes in varieties

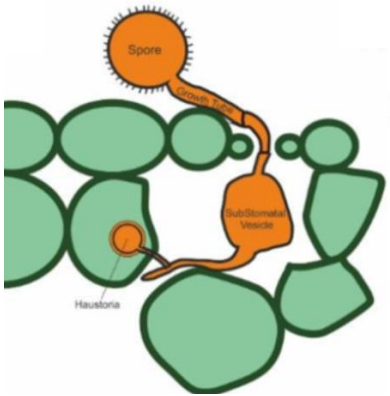


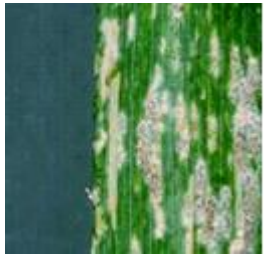
Image: Hassan et al. (2022) *Biosensors*

Types of disease resistance

‘Major gene’ (qualitative) resistance

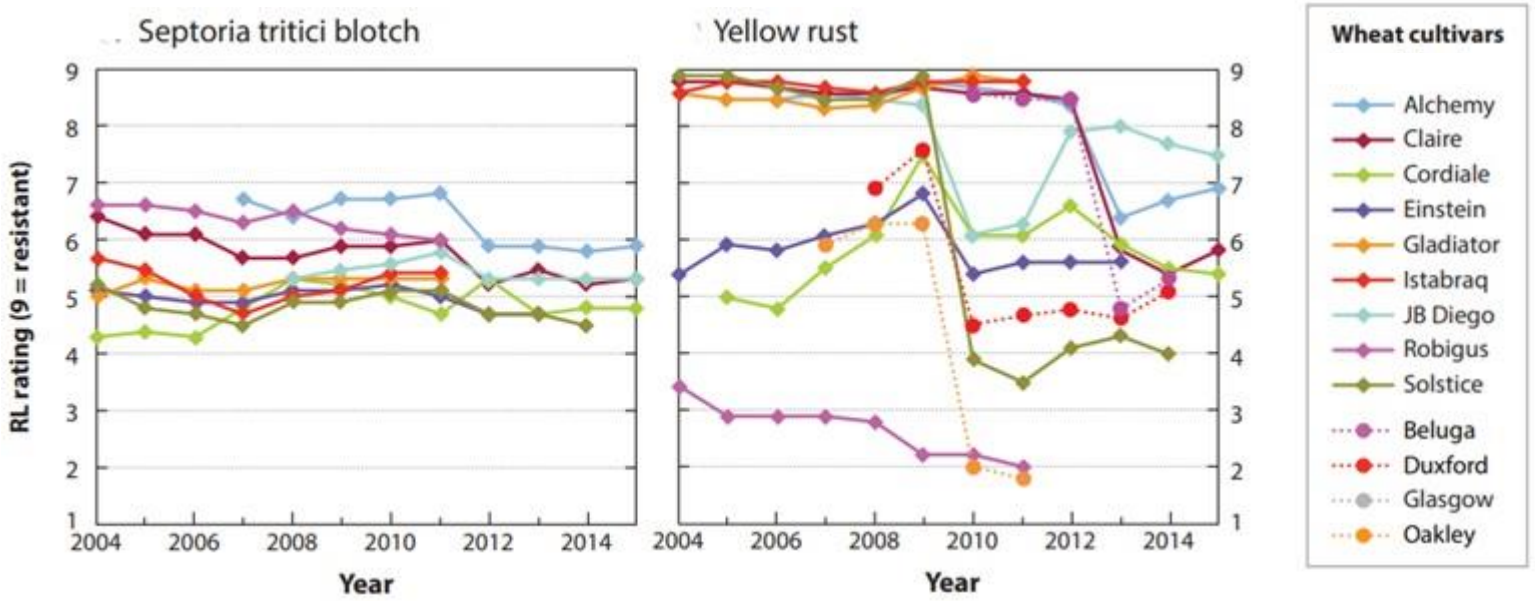
- Usually a single resistance gene of large effect
- Mainly against biotrophic pathogens (rusts and mildews)
- Can provide a high level of resistance: AHDB resistance rating 8-9
- New virulent pathogen strains lead to loss of effectiveness





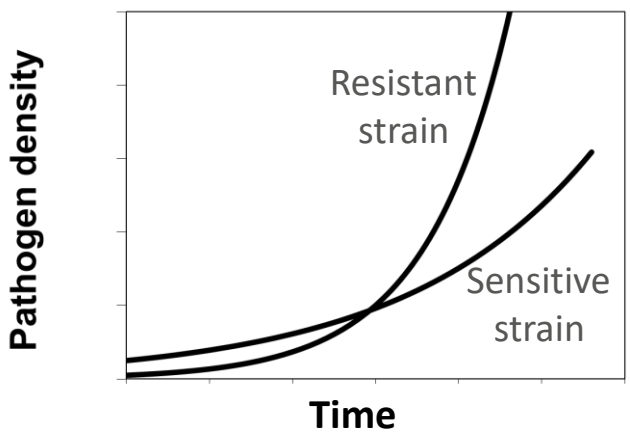
Source: Images AHDB

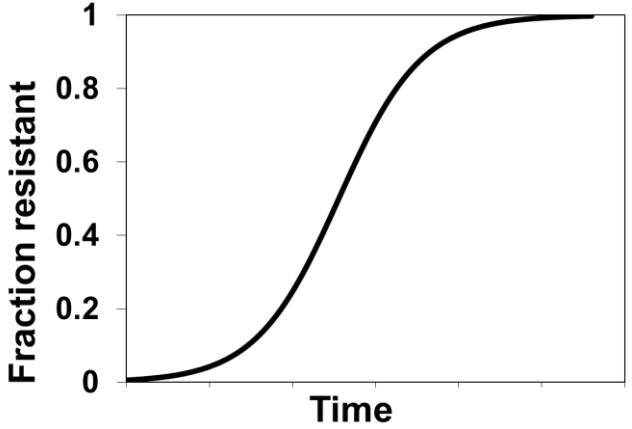
Gradual erosion of disease resistance or ‘boom and bust’



Source: Brown (2015) Annual Review Phytopathology

Fungicide resistance evolution



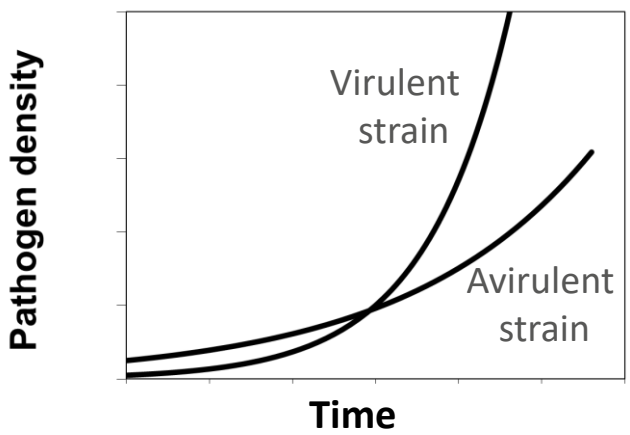


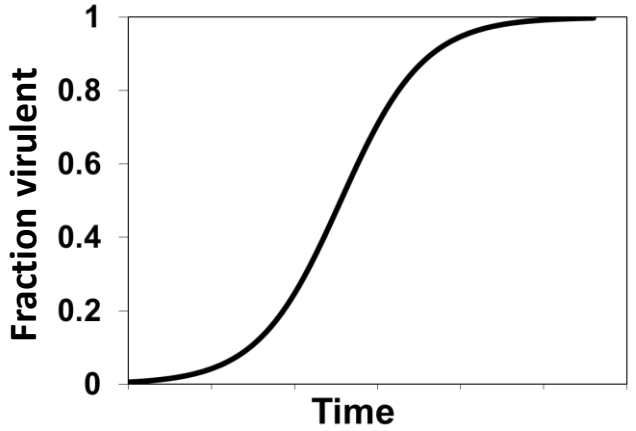
$$\text{Selection} = (r_R - r_S)T$$

*r*R: *per capita* growth rate of the fungicide resistant strain

*r*S: *per capita* growth rate of the fungicide sensitive strain

Virulence evolution



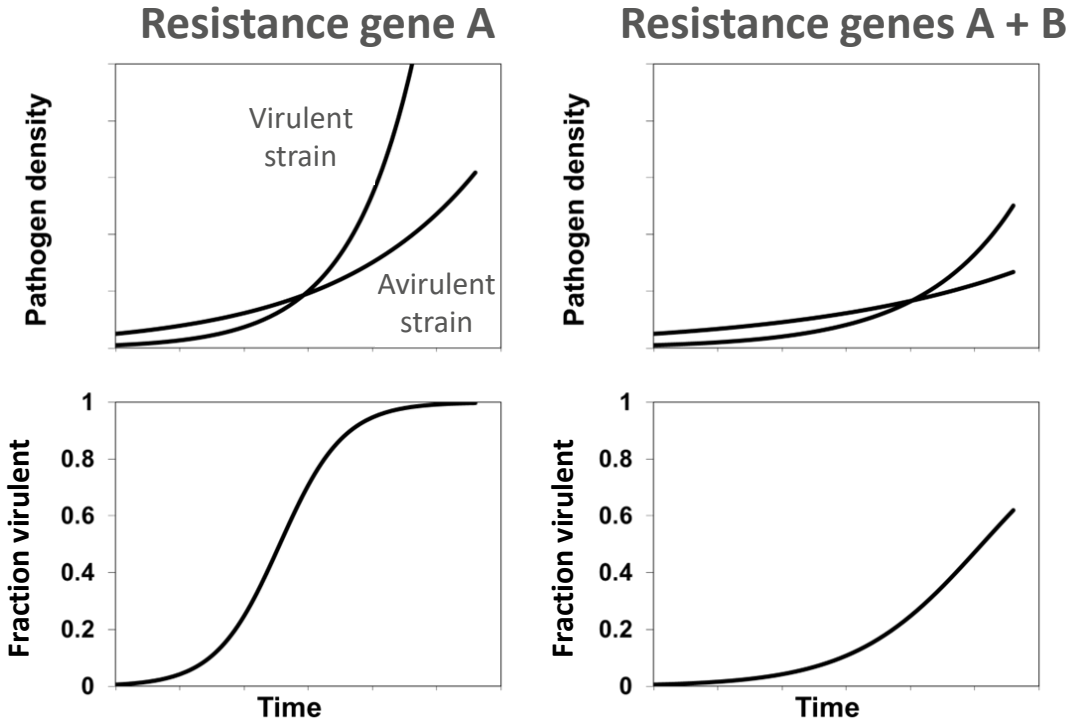


$$\text{Selection} = (r_V - r_A)T$$

rV: *per capita* growth rate of the virulent strain

rA: *per capita* growth rate of the avirulent strain

Adding another disease resistance gene



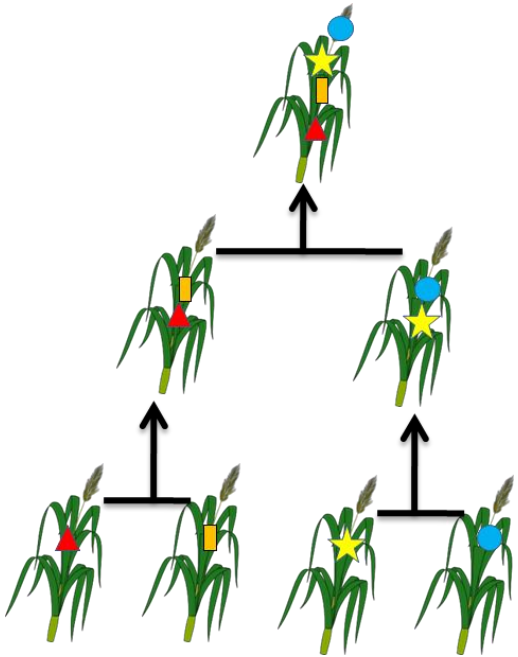
Selection = $(r_V - r_A)T$

Options for deploying disease resistance genes

For a given number of available resistance genes:

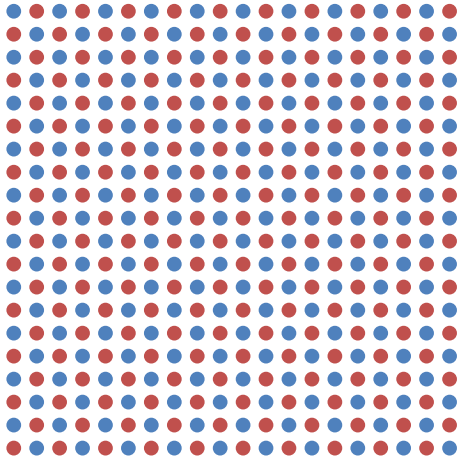
- Put multiple genes in each variety (pyramiding)
  - Major resistance genes
  - Minor resistance genes
  - Combine major and minor genes
  - Create multi-lines
- Put each gene into a different variety
  - Sow varieties as a mixture (variety blend)
  - Sow varieties as a field mosaic
- Combinations of the options above

Pyramiding disease resistance genes

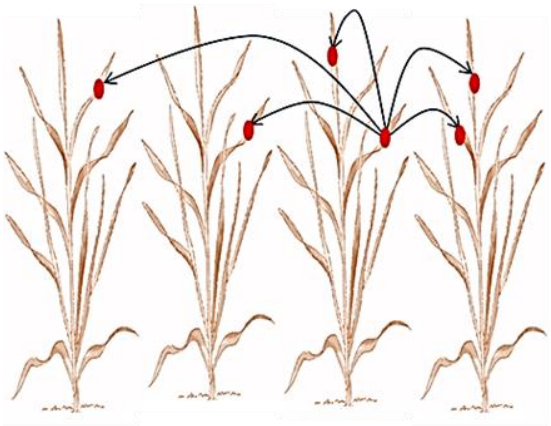


- Pyramiding of minor genes improves disease control
- Resistance gene pyramids are more difficult for pathogens to overcome
- Modelling studies show that pyramiding reduces selection for virulence but little experimental evidence
- Pyramiding major with minor genes can reduce sudden loss of resistance when the major gene is overcome

Mixture of varieties



Susceptible
Resistant

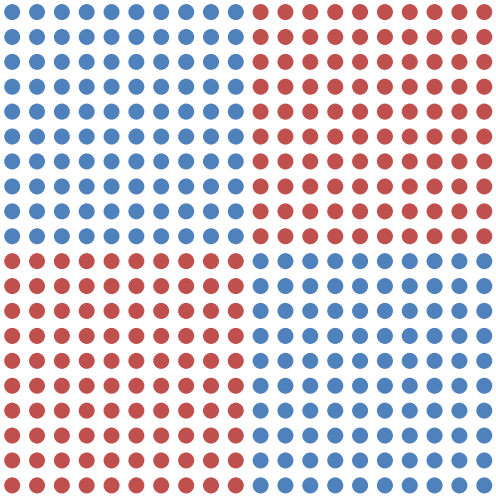


Cultivar mixtures reduce the epidemic growth rate and thus reduce selection for virulence

$$s = (\theta r_V - \theta r_A)T = \theta(r_V - r_A)T$$

θ: fraction of plants resistant

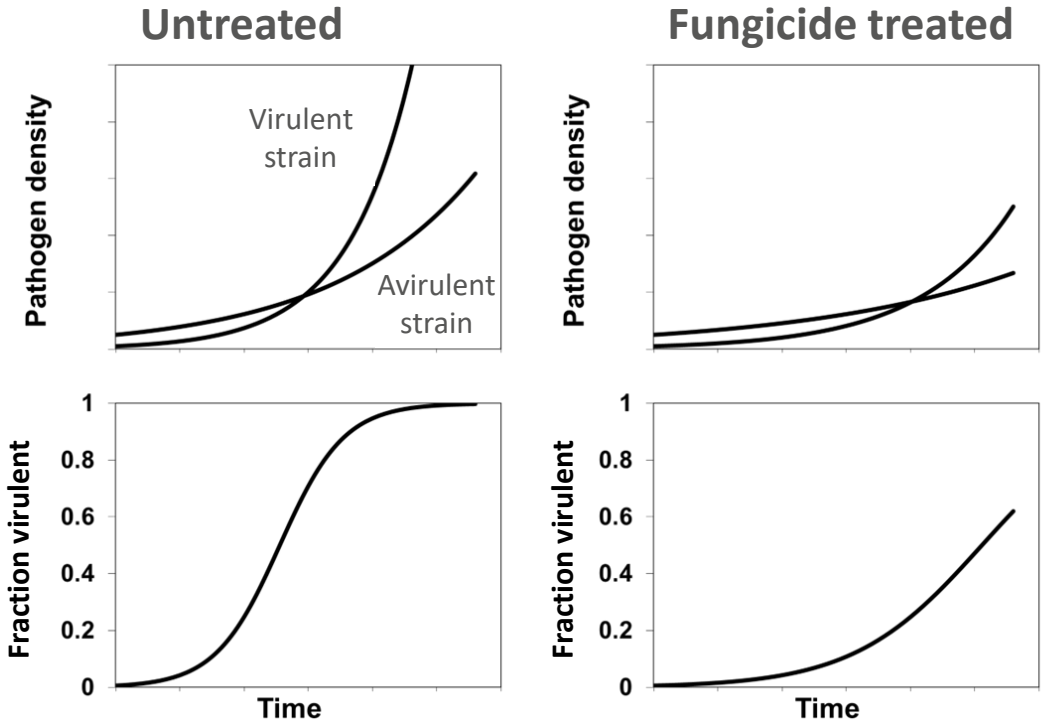
Mosaic of varieties



Susceptible

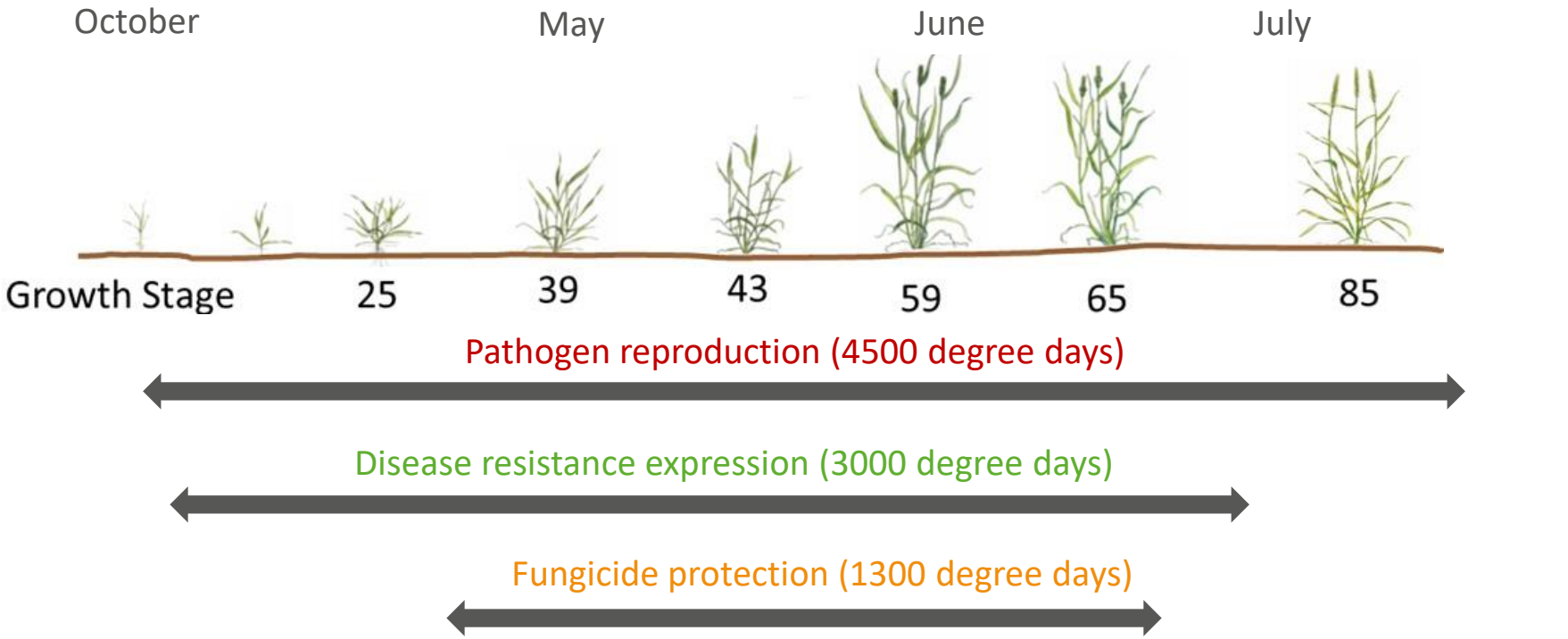
Resistant

Adding fungicide treatment



Selection = $(r_V - r_A)T$

Adding fungicide treatment



Source: Images and dates from AHDB Wheat Growth Guide

How to manage pathogen virulence?

- Pyramiding resistance genes increases the durability of disease control
- Pyramiding major resistance genes with minor genes reduces the sudden loss of control when the major gene is overcome
- Variety mixtures reduce the epidemic growth rate and thus reduce selection for virulence
- Variety mixtures are probably more effective than mosaics
- Potential for mutual protection: variety disease resistance slowing fungicide resistance and fungicides slowing virulence

Further reading

Guidance

Information on variety mixtures: *https://ahdb.org.uk/variety-blend-tool-for-winter-wheat*

Research papers

Brown JKM (2015) Durable Resistance of Crops to Disease: A Darwinian Perspective. *Annual Review Phytopathology* 53:513–39

Fukuoka S, Saka N, Mizukami Y, Koga H, Yamanouchi U, Yoshioka Y, Hayashi N, Ebana K, Mizobuchi R, Yano M (2015) Gene pyramiding enhances durable blast disease resistance in rice. *Scientific reports* 5 : 7773. DOI: 10.1038/srep07773

Kristoffersen R, Eriksen LB, Nielsen GC, Jørgensen JR, Jørgensen LN. Management of Septoria Tritici Blotch Using Cultivar Mixtures. *Plant Disease* (2022)106:1341-1349.

McDonald BA, Linde C. (2002) Pathogen population genetics, evolutionary potential and durable resistance. *Annual Review Phytopathology* 40:349–79

REX Consortium (2016) Combining Selective Pressures to Enhance the Durability of Disease Resistance Genes. *Frontiers Plant Science* 7:1916. doi: 10.3389/fpls.2016.01916

Van den Bosch, F., Verhaar, M.A., Buiel, A.A.M., Hoogkamer, W. & Zadoks, J.C. (1990). Focus expansion in plant disease: IV. Expansion rates in mixtures of resistant and susceptible hosts. *Phytopathology* 80, 598-602.

Van den Bosch, F. (1994). Optimal cultivar mixtures in focal plant disease. *Netherlands Journal of Plant Pathology* **99**, 41-50.

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