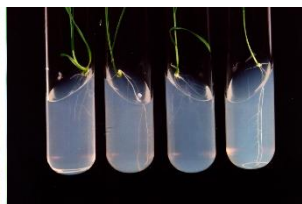




Department
for Environment
Food & Rural Affairs



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

www.adas.co.uk

How to manage fungicide resistance?



How to manage resistance – Part A (previous video)

Number of fungicide applications

Dose per application

Mixtures of fungicide modes of action

Integrated pest management

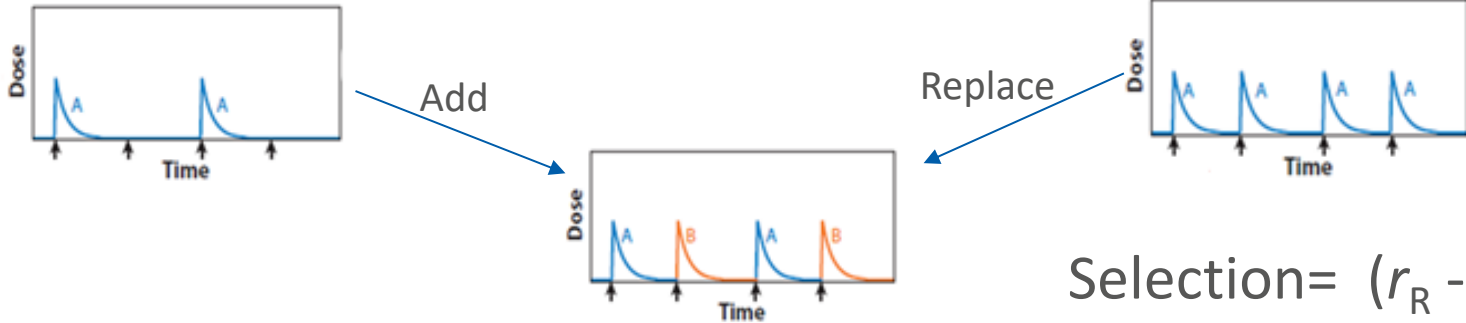
How to manage resistance – Part B (this video)

Alternating modes of action

Alternation or mixtures?

Spray timing

Alternating modes of action

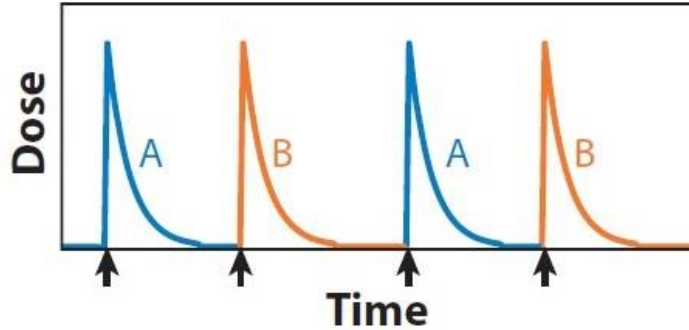


$$\text{Selection} = (r_R - r_S)T$$

Global evidence across pathogens and modes of action:

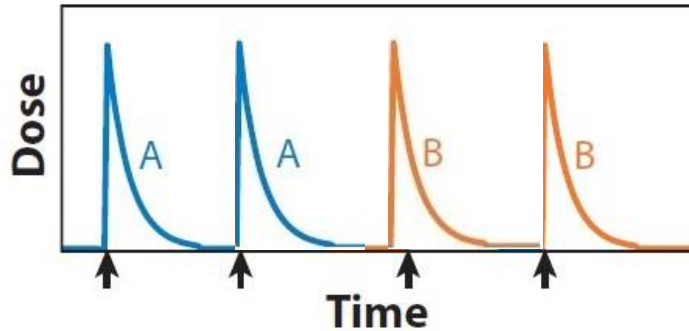
	Increase selection	No effect	Decrease selection
Alternate (add sprays)	1	4	0
Alternate (replace sprays)	1	2	9

'Strict' alternation or 'block' alternation?



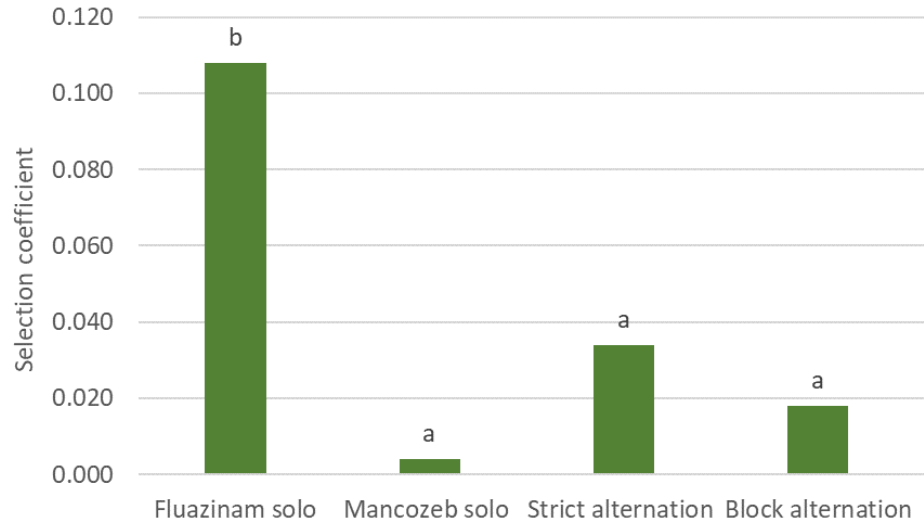
Alternation works by Strategy 3:
Reduce time pathogen exposed to fungicide

Strict or block alternation have similar
exposure time



'Strict' alternation or 'block' alternation?

Selection for fluazinam resistant clonal lineage 37-A2. Three field trials 2020 to 2022.
Six fungicide applications at 7 day intervals

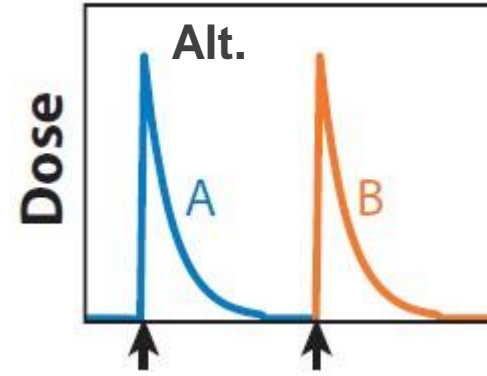
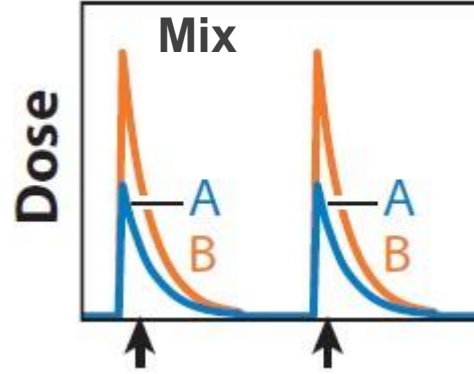
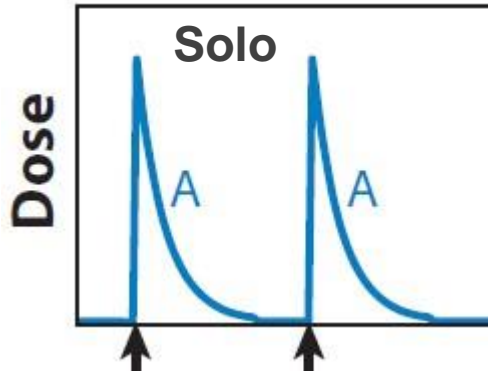


Phytophthora infestans

Strict alternation = alternating fluazinam then mandipropamid or vice versa (mean)

Block alternation = three fluazinam then three mandipropamid or vice versa (mean)

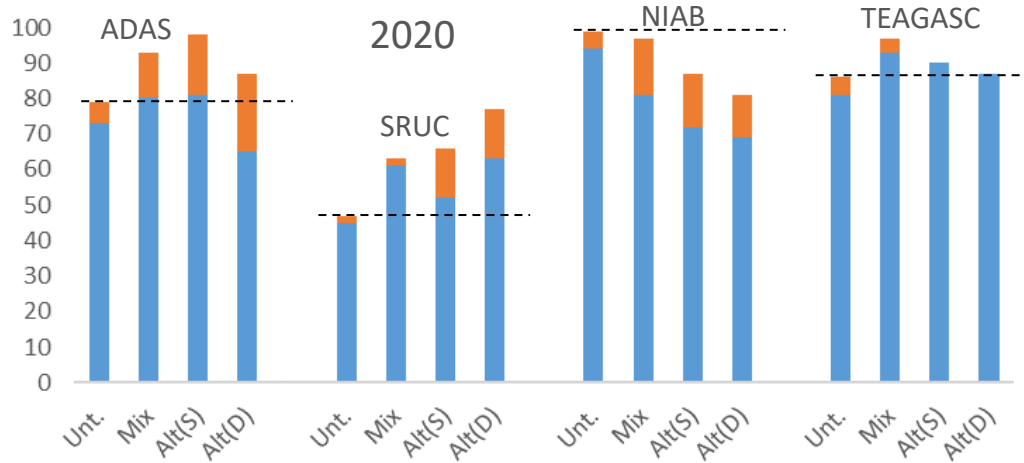
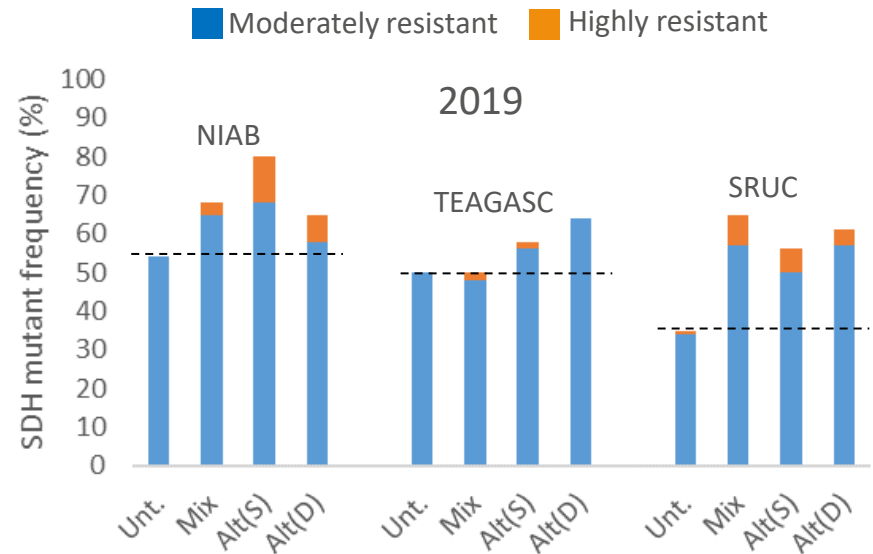
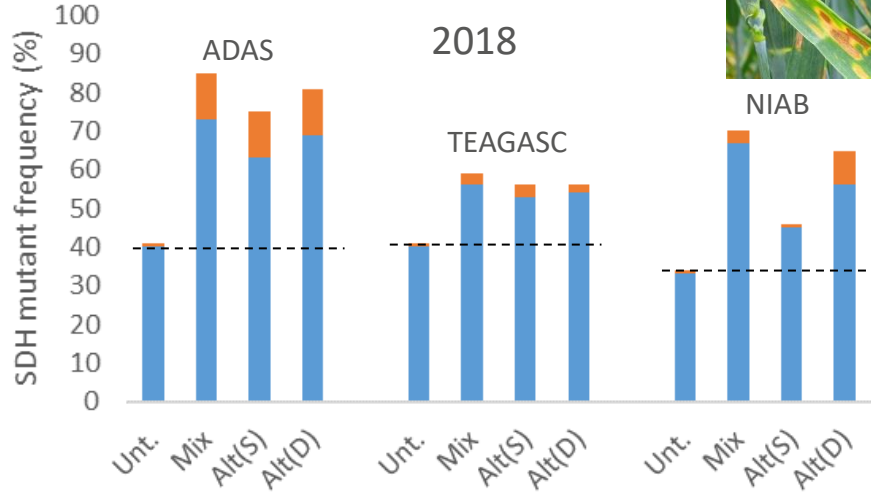
Alternate or mix?



Global evidence across pathogens and modes of action:

	Increase selection	No effect	Decrease selection
Mix compared to alternate	2	1	4

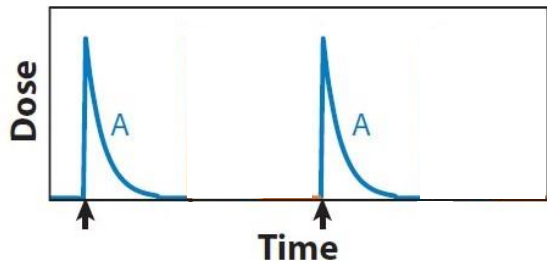
Alternate or mix?



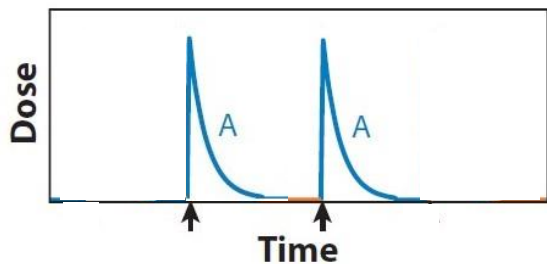
Same total dose of SDHI and DMI in mixture and alternation treatments

Source: Young et al. (2021)
AHDB project report PR637

Spray timing



Strategy 1: Reduce growth rates of resistant and sensitive strains



Strategy 2: Reduce growth rate of resistant strain relative to sensitive strain

Strategy 3: Reduce time pathogen exposed to fungicide

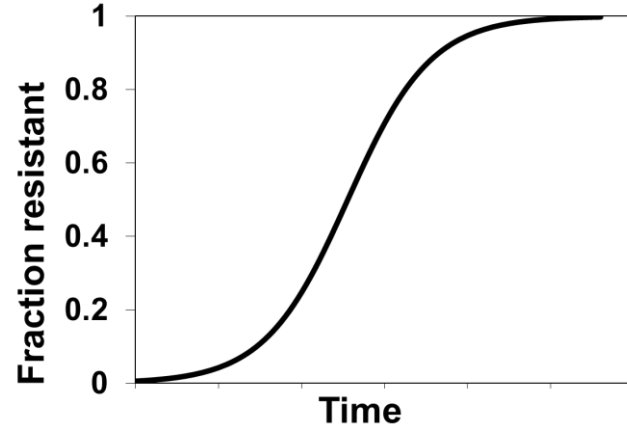
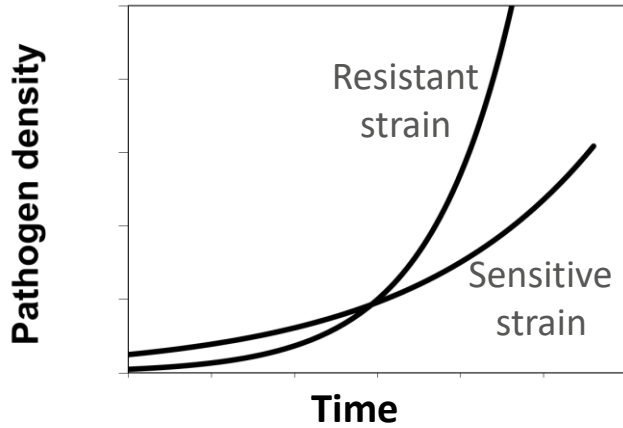
	Increase selection	No effect	Decrease selection
Adjust treatment timing	3	1	2

Is this resistance management guidance?



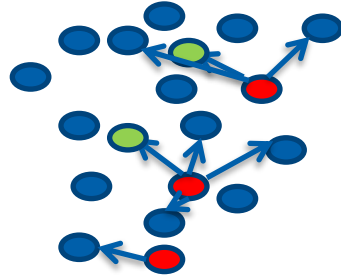
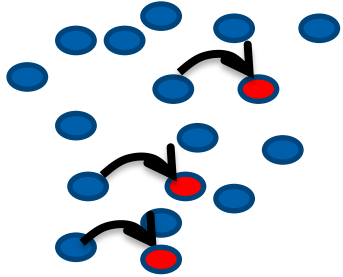
- “Treat early while the pathogen population is low”
 - “Avoid eradicator/curative treatment”
-

Treat early while the population size is low?

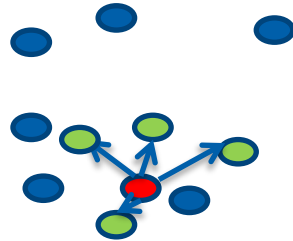
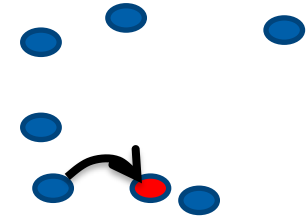


$$\text{Selection} = (r_R - r_S)T$$

Treat early while the population size is low?



- A smaller population results in:
- Fewer resistant mutants
 - Higher proportion of mutants surviving



Mutation

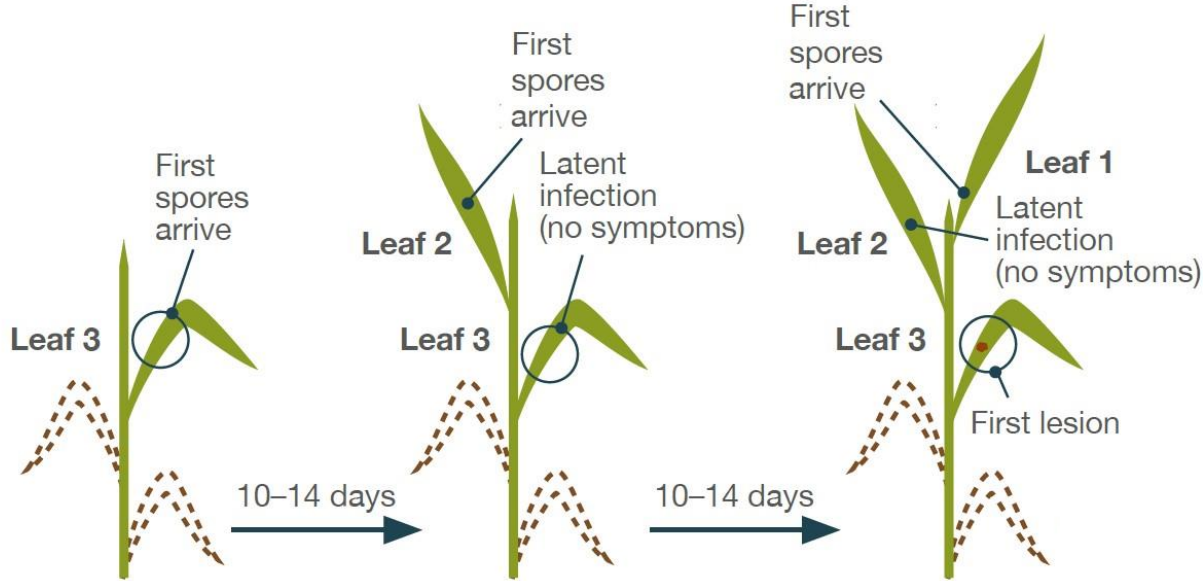
Invasion

Avoid eradicant/curative treatment?

GS32
Leaf 3 just emerged

GS33
Leaf 2 just emerged

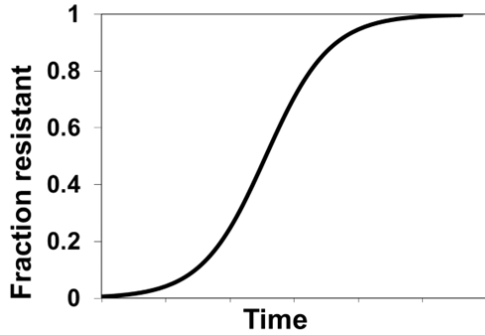
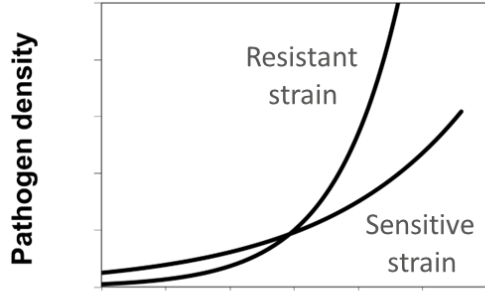
GS39
Flag leaf emerged



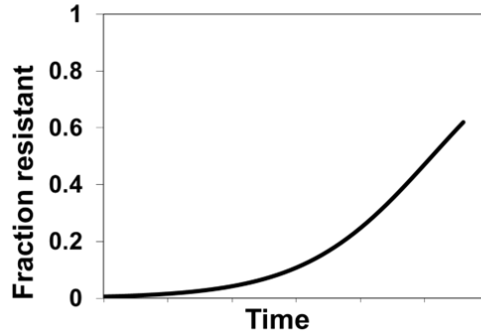
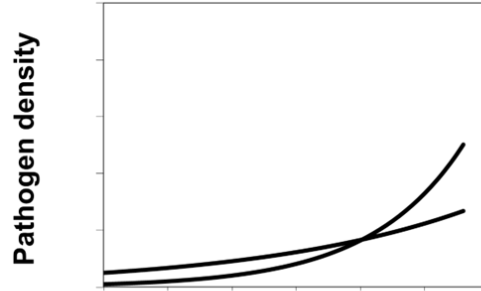
Avoid eradicator/curative treatment?



Solo fungicide A



Mixture fungicides A + B



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

How to manage fungicide resistance?



- Mixtures or alternation of modes of action reduce selection for fungicide resistance.
 - Choice between mixtures or alternation can be determined by efficacy and practical considerations.
 - Choice between 'strict' and 'block' alternation can be determined by efficacy and practical considerations
 - Choice of spray timing can be determined by efficacy and practical considerations
 - Optimising spray timing for efficacy should also provide good resistance management.
-

Further reading



Guides

Guidance from the UK Fungicide Resistance Action Group (FRAG-UK): <https://ahdb.org.uk/knowledge-library/the-fungicide-resistance-action-group-frag-uk>

Guidance from the industry Fungicide Resistance Action Committee (FRAC): <https://www.frac.info/>

Book

Understanding and minimising fungicide resistance (2023). Edited by: Lopez-Ruiz FJ. Published by: Burleigh Dodds

Research papers, mainly by the authors, on the theme of this video

Young, C, Boor, T, Corkley, I, Fraaije, B, Clark, W, Havis, N, Kildea, S, Paveley, N (2021). Managing resistance evolving concurrently against two or more modes of action, to extend the effective life of new fungicides. AHDB final report PR637.

van den Bosch, F., Oliver, R., van den Berg, F. and Paveley, N. (2014) Governing principles can guide the development of fungicide resistance management tactics. Annual Review of Phytopathology, 52:175–95.

Hobbelen, P, Paveley, N, Oliver, R, and van den Bosch, F (2013) The Value of Alternation or Mixtures of Fungicides for Delaying the Selection of Resistance Against Two Modes of Action in Populations of *Mycosphaerella graminicola* on Winter Wheat. Phytopathology, 101:690-707.

Hobbelen, P, Paveley, N, and van den Bosch, F (2014) A stochastic simulation model describing the emergence of resistance to pesticides. Plos One, vol 9, e91910. doi:10.1371/journal.pone.0091910.

Mikaberidze A, Paveley N, Bonhoeffer S, and van den Bosch F (2017) Emergence of resistance to fungicides: the role of fungicide dose. Phytopathology 107: 545-560.

Young C, van den Bosch F, Fraaije B, Burnet F, King S, Gosling P, Paveley N (2017) Strategies to delay the development of fungicide resistance: Alternation, mixtures or restricting the number of treatments? Aspects of Applied Biology 134, Crop Production in Southern Britain,37.

van den Berg, F., van den Bosch, F., and Paveley, N (2013). Optimal fungicide application timings for disease control are also an effective anti-resistance strategy: A case study for *Zymoseptoria tritici* (*Mycosphaerella graminicola*) on wheat. Phytopathology 103: 1209-1219.

Many excellent papers are available by other authors. The chapters of the fungicide resistance book listed above contain comprehensive bibliographies

If a research paper is not open-access you can request a copy by contacting authors through www.researchgate.net