Fungicide resistance management

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Introduction

- Resistance management strategies should be based on evidence

- Example statement: ‘’It is important to use the maximum dose permitted on the product label, in order to prevent, or at least slow down, the development of resistance.’’

Are there governing principles?

Governing Principles Can Guide Fungicide-Resistance Management Tactics

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Keywords

resistance management, governing principle, strategy, tactic, selection coefficient, exposure time, dose, mixture, alternation, spray timing

Abstract

Fungicide-resistance management would be more effective if principles governing the selection of resistant strains could be determined and validated. Such principles could then be used to predict whether a proposed change to a fungicide application program would decrease selection for resistant strains. In this review, we assess a governing principle that appears to have good predictive power. The principle states that reducing the product of the

Governing principles

Based on Milgroom & Fry (1988) and Staub & Sozzi (1983)

- The selection coefficient:

$$sT = (r_R - r_S)T$$

Rate of increase of resistant strain

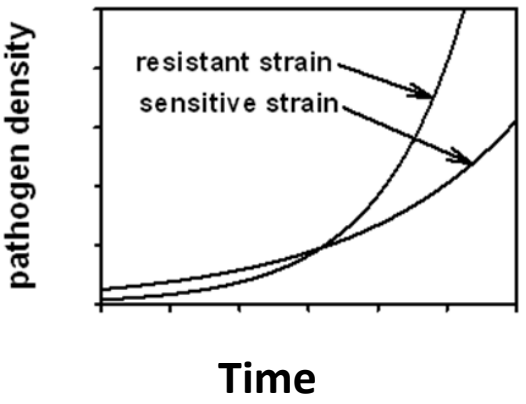
Rate of increase of sensitive strain

Exposure time

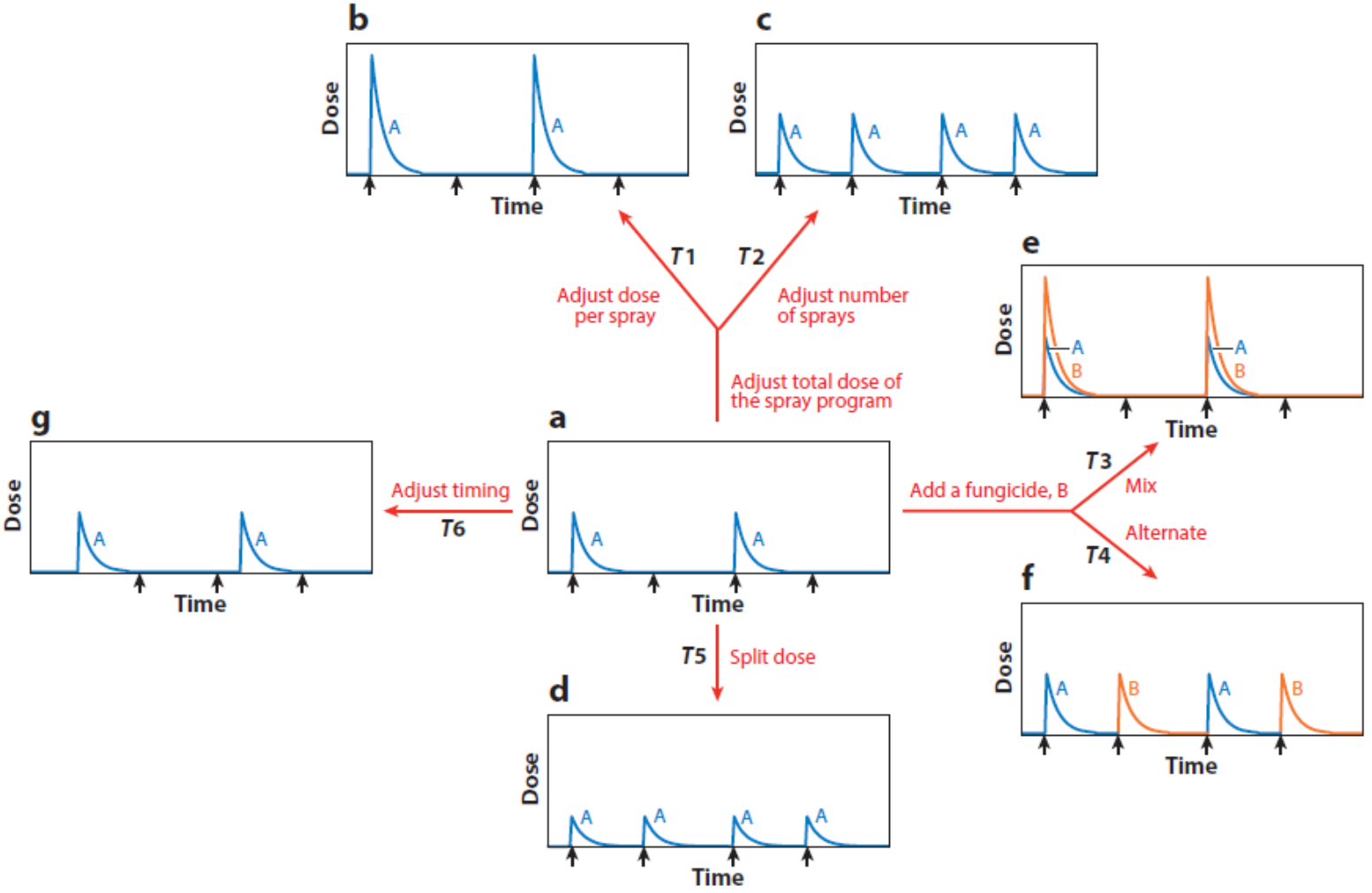
Strategy 1: Reduce both r_R and r_S

Strategy 2: Reduce r_R relative to r_S

Strategy 3: Reduce exposure time



Tactics investigated



Success of tactics summary

		increase	No effect	decrease	total
T1	Increase dose	**16**	1	2	19
T2	Increase spray number	**6**	0	0	6
T5	Split the dose	**10**	0	1	11
T3	Mix: add a fungicide	1	6	**46**	53
T4	Alternate	1	**4**	0	5
T6	Adjust spray timing	3	1	2	6

- $sT = (r_R - r_S)T$

Adding a mixing partner: strategy 1

- $sT = (r_R - r_S)T$
- A mixing partner affects r_R and r_S in the same way
- Strategy 1 applies: reduce both r_R and r_S

	Adding a mixing partner ..... selection			
	increase	No-effect	decrease	
Multi-site	1	3	**27**	31
Single-site	0	3	**16**	19

- General conclusion: as expected adding a mixing partner reduces selection for resistance

Adding a mixing partner – further details

Phytopathology
REVIEW

Mixtures as a Fungicide Resistance Management Tactic

Frank van den Bosch, Neil Paveley, Femke van den Berg, Peter Hobbelen, and Richard Oliver

First, third, and fourth authors: Rothamsted Research, West Common, Harpenden, AL5 2JQ, United Kingdom; second author: ADAS High Mowthorpe, Dugglesby YO17 8BP, United Kingdom; and fifth author: Environment & Agriculture, Centre for Crop and Disease Management (CCDM), Curtin University, Bentley, WA 6102, Australia.
Accepted for publication 14 August 2014.

ABSTRACT

van den Bosch, F., Paveley, N., van den Berg, F., Hobbelen, P., and Oliver, R. 2014. Mixtures as a fungicide resistance management tactic. Phytopathology 104:1264-1273.

The effect of dose: strategy 2

- $sT = (r_R - r_S)T$
- An increased dose reduces r_S more strongly than r_R

	Increased dose …… selection			
	increase	no effect	decrease	Total
experiments	**16**	1	2 (1)	19
models	**8**	0	0	8

- Contrary to general held opinion there is clear evidence that an **increased dose increases selection**
- **Careful: we are not advocating to reduce dose as this may compromise effective control!**

The effect of dose – further details

Plant Pathology (2011) 60, 597–606

Doi: 10.1111/j.1365-3059.2011.02439.x

REVIEW

The dose rate debate: does the risk of fungicide resistance increase or decrease with dose?

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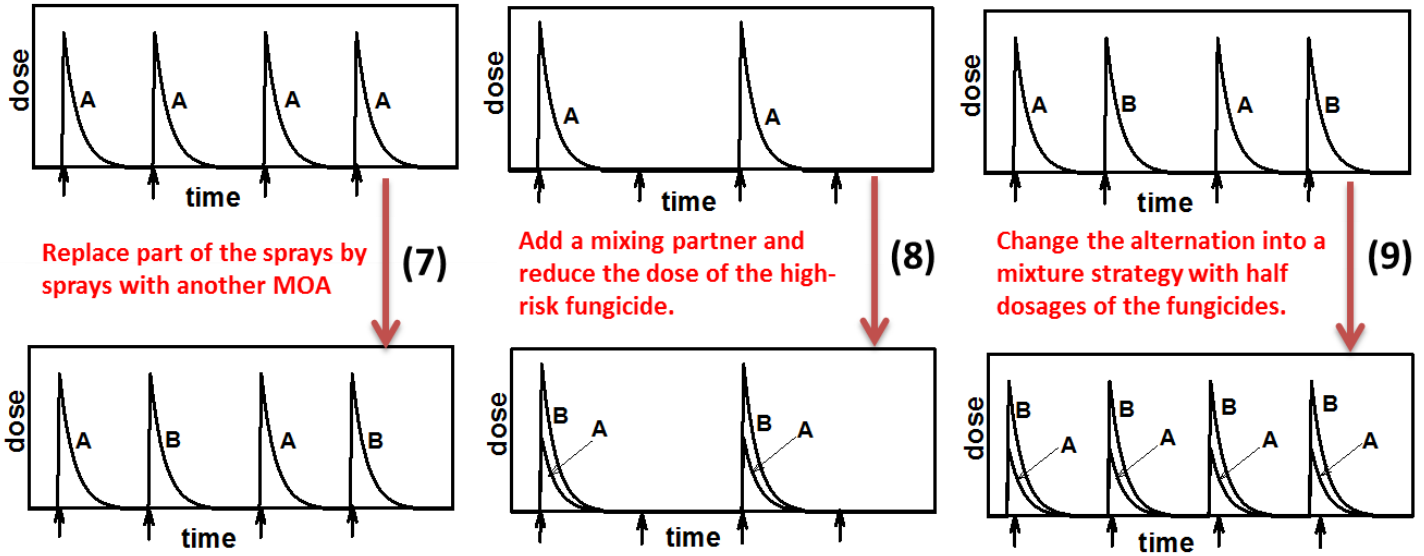
Number of applications: strategy 3

- $sT = (r_R - r_S)T$
- An increased number of applications increases the time-span over which selection acts

	increase	No effect	decrease	total
Increase spray number	**6**	0	0	6

- General conclusion: an increased number of spray applications increases selection

Practical resistance management tactics



		increase	no effect	decrease	total
T7	Replace a spray	0	3	**12**	15
T8	Mix and reduce dose	1	5	**17**	23
T9	Alternate versus mixing	2	4	6	12

Summary

- Very simple governing principle can explain effect of fungicide resistance management tactics on selection for resistance in majority of cases
- 84% of published cases agree with prediction
- 5% of published cases contradict predictions

- Useful tool to inform decisions about fungicide resistance management when there is no time to wait for the accumulation of new evidence

Thank you for your attention!

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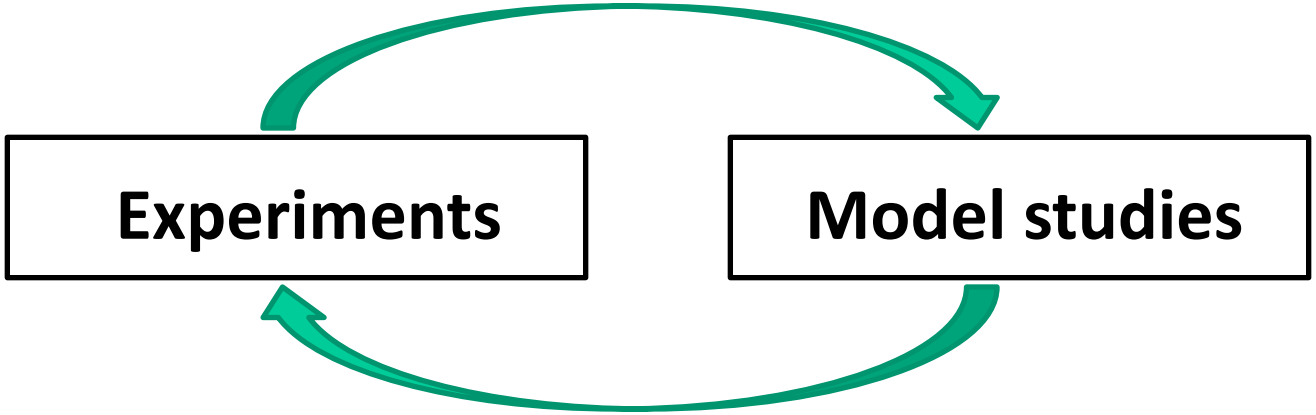
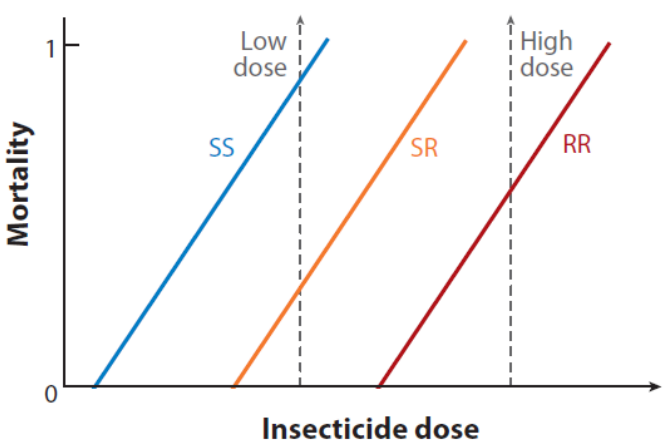
Introduction

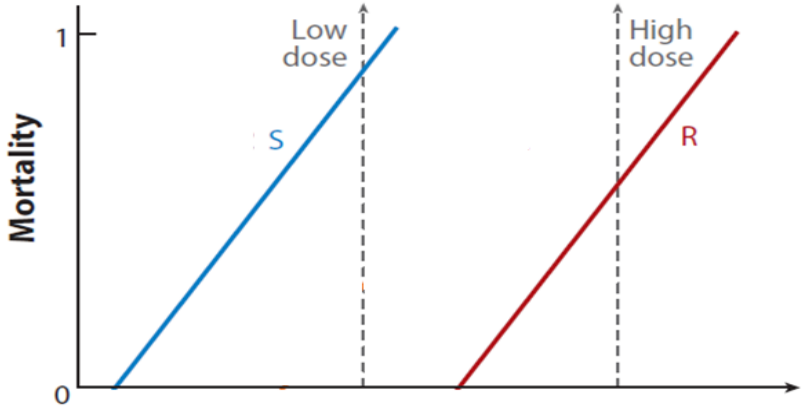


- Combining field experiments and modelling
- Governing principle, qualitative
- Dynamic models, towards quantitative
- Guide field research on resistance management
- Results influence policy through FRAC, FRAG, CRD, EPPO

Link to insecticide resistance literature

- The heterozygote is partially sensitive
- At low frequency R genes are, due to sexual reproduction, mainly in heterozygotes





- Most plant pathogens are haploid at time when fungicide is applied, or are clonal
- Reasoning of insecticide resistance does not apply

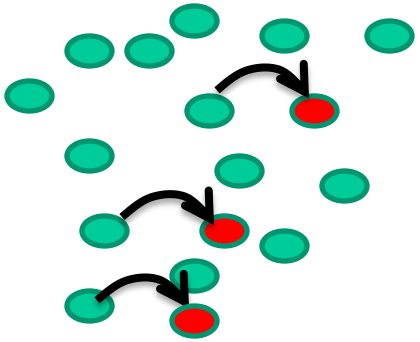
Fungicide dose, missing evidence

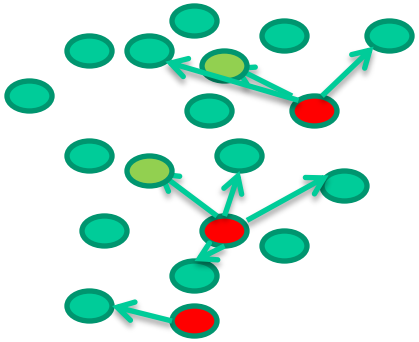
- Mechanisms by which an increased dose may reduce resistance risk
  - Stress induced mutation
  - Mutation limitation (emergence)
  - Refugia
  - Converging dose-response curves
  - Partial resistance/multi-gene resistance
- These mechanisms are hypothetical, none have been shown to apply
- Virtually all available evidence suggests that increasing fungicide dose increases selection for resistance

3 The effect of Dose.

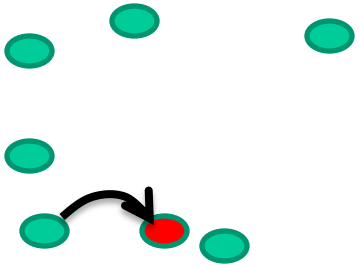
Mutation limitation and emergence

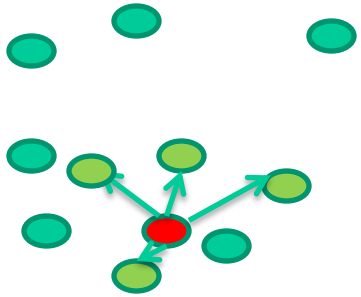
Low dose





High dose



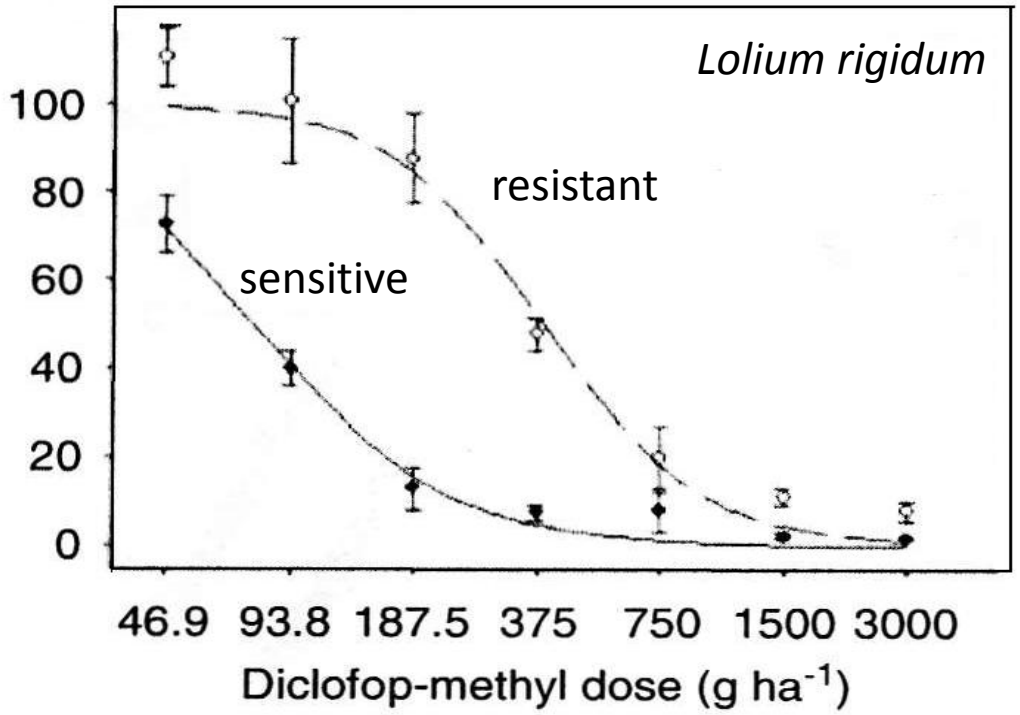


Mutation

Invasion

Fungicide dose, missing evidence

- Converging dose-response curves



Neve & Powels (2005)

Adjust timing – protective vs curative

- Strictly:
  - Protectant : application prior to infection
  - Curative: application after infection

- Brent and Hollomon (2007)

"to the authors knowledge there is no experimental evidence comparing the resistance risks of prophylactic versus threshold-based schedules, and research on this would be useful."

Adjust timing – protective vs curative

$$sT = (r_R - r_S)\,T$$

	increase	No effect	decrease	total
adjust timing	3	1	2	6

- Protective use is in many cases essential for effective disease control
- There is no evidence that protective use is essential for resistance management