Fungicide resistance stewardship

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Leading the way in Agriculture and Rural Research, Education and Consulting

Challenges and choices 2020

Pesticide withdrawals

Evolving diseases and resistance

New products

- What are the resistance issues and how can we manage them?
- Where and when to use new and existing products?

- Chlorothalonil withdrawal

(Authorisation ends: (a) 20 November 2019 for sale and distribution & (b) 20 May 2020 for the disposal, storage and use of existing stocks)

Resistance - threat of additional losses

- Fungicide resistance is eroding established actives and threatening newer ones
- Current resistance status for major arable crops is building
- Adds to input costs and reduces outputs

- What are the principals of resistance management?
- What information is available and useful
- How can we apply it?
- Opportunity and necessity to improve practice

Revystar XE

New fungicide product for 2020

- Contains a new triazole (Revysol) and an SDHI (Xemium)
  - 100 g/L mefentrifluconazole + 47.5 g/L fluxapyroxad
- Maximum individual dose 1.5 L/ha
- Maximum of two applications
- To be applied before GS69
- Approved for wheat, barley, oats, rye, triticale, spelt and durum wheat

30 Jul Assessment following GS32 and 39 applications

Inatreq™

- Currently waiting approval and should be launched in 2020
- Contains fenpicoxamid
- Derived from a natural compound produced by fermentation of an Actinomycete (Streptomyces spp.)
- New mode of action - Quinone Inside Inhibitor (Qil) blocking mitochondrial respiration
- No cross-resistance to existing cereal fungicides but single site active so needs careful stewarding against resistance
- To be used once and only in mix with other actives to minimize the risk of resistance development.
- Best used as a protectant treatment or in the earliest stages of disease development.

Cereals: resistance issues

Fungicide Group	Diseases affected
Strobilurins	mildew (wheat and barley), septoria, net blotch, tan spot, ramularia, rhynchosporium, M. nivale
Azoles	mildews, septoria, ramularia, rhynchosporium, tan spot
SDHIs	net blotch, septoria, ramularia, tan spot
MBCs (no longer used)	eyespot, septoria, M. nivale, ramularia
Quinoxyfen	wheat mildew, barley mildew
Metrafenone	wheat mildew, barley mildew
Chlorothalonil	None
Folpet	None

Have we learned anything???

- Before launch the base-line sensitivity and normal range determined
- Risk assessment made and resistance management plans put in place and assessed by approving authority
- Mix of statutory and stewardship measures
- Decisions will impact on grower profit and industry return on investment so evidence has to be both robust and pragmatic
- Monitoring part of conditions of approval for higher risk products

Resistance management issues

- Stewardship measures based on reduced reliance
- Heavy usage of an a.i. confers a massive advantage to any resistant individuals
- Advice is to use all available methods to reduce pressure on chemistry – mix, alternate, use low-risk multisites
- Difficulties in motivating industry to be collectively responsible
- Complex science, confused messages

Fungicide Resistance Action Group - UK

25 Members - Independent researchers, Crop Protection Association, Fungicide Resistance Action Committee, agronomists, regulator.

- Gather and interpret reports of fungicide resistance issues and arrive at UK consensus view
- Promote practical guidelines on status and management of fungicide resistance in UK
- Produce, publish and promote educational material that will assist in the understanding of and reduce the incidence of resistance in plant pathogens.
  - Website and Guidelines
  - Recommendations for label restrictions / changes

https://cereals.ahdb.org.uk/frag

More practical messages and higher profile?

Fungicide Futures – supported by AHDB

- Combine anti-resistance management information, developed and published by FRAG-UK, with the power of AHDB's communications channels
- Stronger anti-resistance advice and consistent messages
- Focus on converting anti-resistance science into on-farm practice
- Putting anti-resistance at the heart of fungicide programme planning futures
- Messages timed with key growth stages
- Published on the AHDB website at cereals.ahdb.org.uk/fungicidefutures

Generic anti-resistance strategies

- Follow IPM principles and use pesticides in targeted and sustainable ways
- Make full use of alternatives
- Reduce reliance on fungicides
- Use as little fungicide as necessary to do the job (both dose and number of applications)
- Use balanced mixtures of products
- Alternate products
- Avoid multiple repeat dose programmes
- Utilise low risk fungicides (multisites)

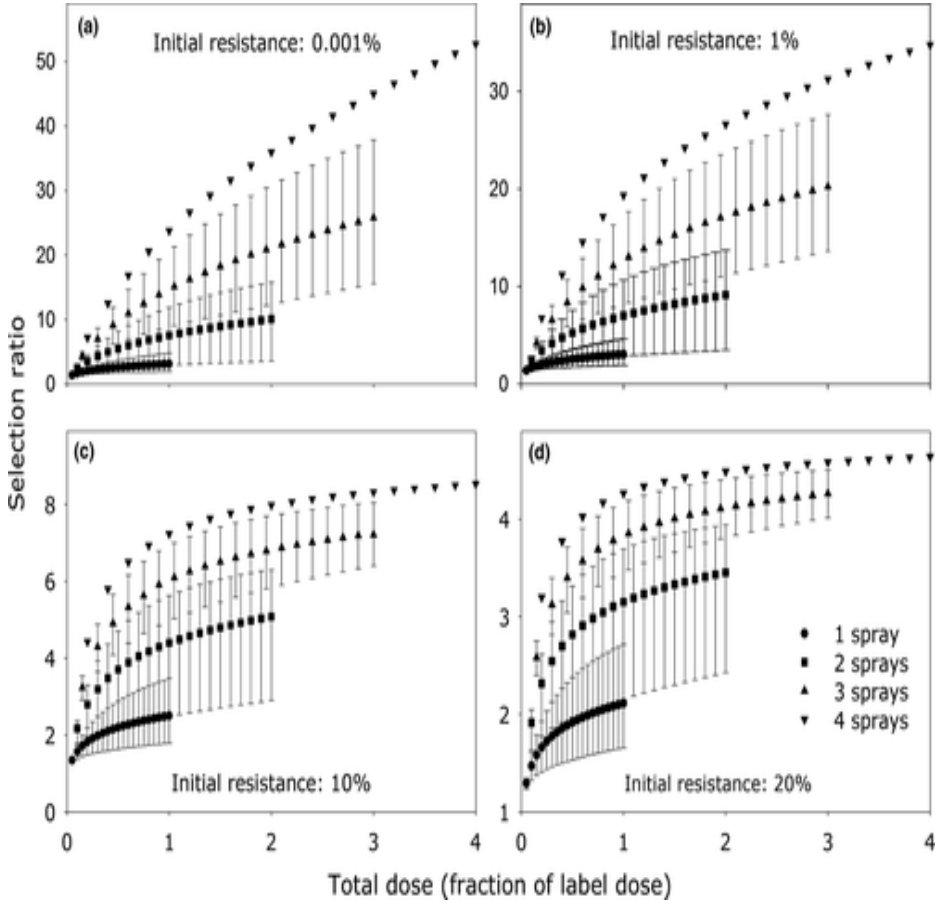
- Difficulties in getting stewardship principles taken up in practice
- Difficulties in motivating industry to take responsibility

What's the evidence?

	Increase selection	No effect	Decrease selection
Increase dose	16	1	2
Increase spray number	6	0	0
Split the dose	10	0	1
Add mixture partner	1	6	46
Alternate (replace sprays)	1	2	9
Adjust timing	3	1	2

van den Bosch et al. 2014 Governing principles can guide resistance management tactics
Annual Review Phytopathology

Dose and number of applications that maximize fungicide effective life - exemplified by Zymoseptoria tritici on wheat

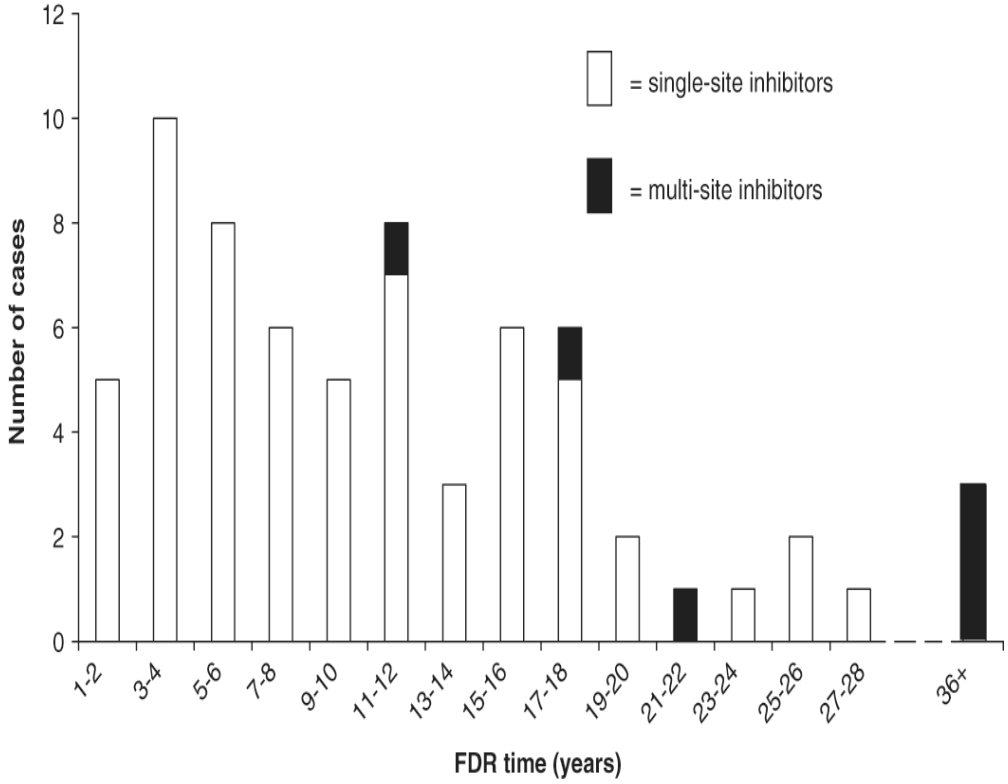


- A model analysis for a fixed number of applications,
- Selection ratio increases with the total dose in the spray programme.
- Selection is greatest at highest total dose

Plant Pathology, Volume: 65, Issue: 8, Pages: 1380-1389, First published: 23 May 2016, DOI: (10.1111/ppa.12558)

Frequency distribution of time from fungicide introduction to first detection of resistance (FDR time) for 67 cases of resistance in plant pathogens in Europe.

Evaluation of a matrix to calculate fungicide resistance risk



Pest Management Science, Volume: 70, Issue: 6, Pages: 1008-1016,
First published: 06 September 2013, DOI: (10.1002/ps.3646)

The effect of mixing a low-risk and a high-risk fungicides on the number of growing seasons before resistance to the high-risk fungicide emerges in a population of M. graminicola on winter wheat.

Dose rate of the low-risk fungicide[d]	Dose rate of the high-risk fungicide[d]									
	10	20	30	40	50	60	70	80	90	100
0	46[e]	21[e]	15[e]	13[e]	11	10	9	9	9	8
10	55[e]	23[e]	17[e]	14	13	11	11	10	10	9
20	65[e]	25[e]	18	14	13	12	11	11	10	9
30	73[e]	27[e]	19	15	13	12	11	11	10	10
40	78[e]	27[e]	19	16	14	13	12	11	11	10
50	78[e]	29[e]	20	16	14	13	12	11	11	10
60	82[e]	29	20	16	14	13	12	11	11	11
70	80[e]	28	20	16	14	13	12	12	11	11
80	81[e]	28	20	16	15	13	12	11	11	11
90	81[e]	28	20	16	14	13	12	12	11	11
100	81[e]	28	19	16	14	14	12	12	11	11

[a]The low-risk fungicide was assumed to be not at-risk of resistance development, but unable to provide sufficient disease control when used alone. The resistant strain was assumed to be completely insensitive to the high-risk fungicide.
[b]The resistant strain was considered to have emerged when the number of resistant lesions reaches or exceeds a threshold (see text).
[c]The emergence times in the table were calculated for the default scenario, which assumes that i) fitness costs of resistance reduce the infection efficiency of the resistant strain by 10%, ii) resistance to the high-risk fungicide is complete and iii) a mutation probability amounting to $1.13 \cdot 10^{-16}$.
[d]Fungicide doses are expressed as a fraction of the label recommended dose.
[e]Combinations of dose rates of the low-risk and high-risk fungicide that do not provide sufficient control of an average epidemic of *M. graminicola* on winter wheat. Effective disease control was defined as a disease-induced loss of healthy leaf area duration during the yield forming period equal to or below 5% [18].
doi:10.1371/journal.pone.0091910.t002

Minimise use of high risk partner and maximise low risk partner

Hobbelen PHF, Paveley ND, van den Bosch F (2014) The Emergence of Resistance to Fungicides. PLOS ONE 9(3): e91910. https://doi.org/10.1371/journal.pone.0091910
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091910

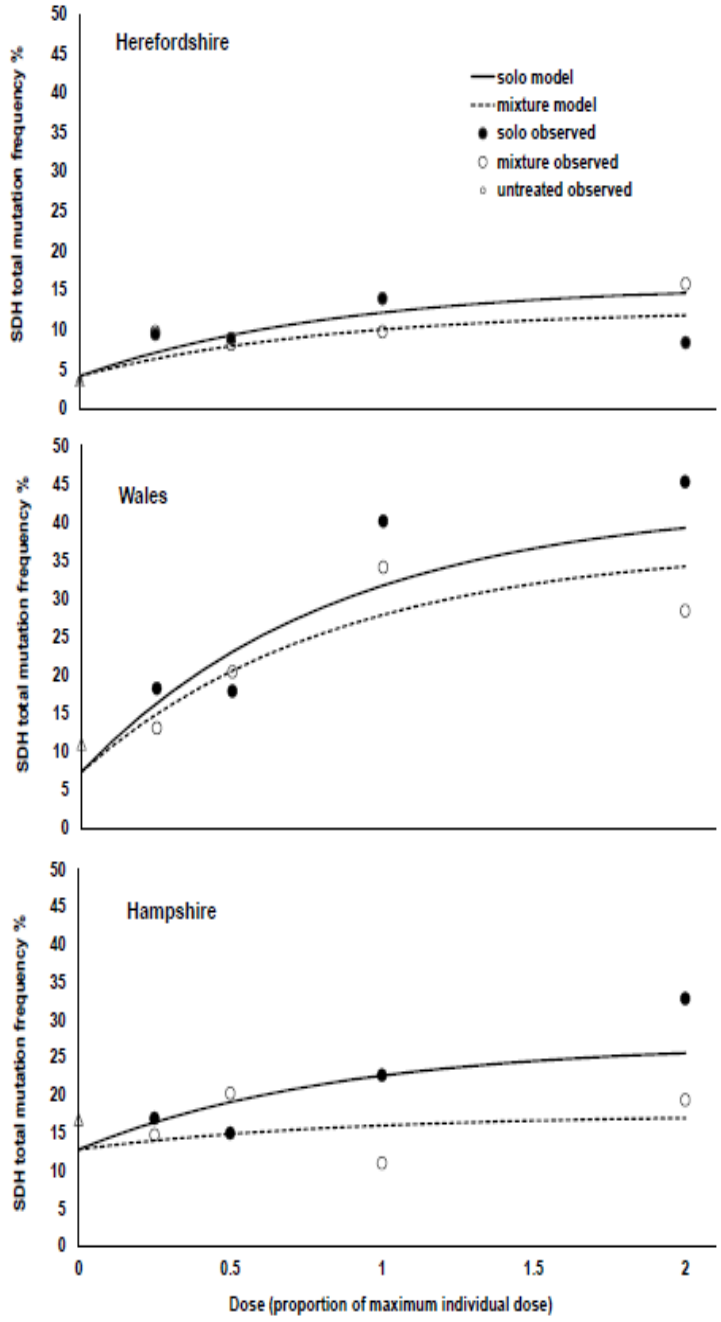
PLOS ONE

Confidence that:-

- Low dose rates of fungicides do not increase risk
- High doses do increase resistance risk
- Increased number of sprays does increase resistance risk

Reducing reliance on individual ai's

- Mixtures and alternations reduce risk



SRUC

Focus of current research

…..Stewarding SDHIs and azoles

Advantages and disadvantages of mixing two single-site acting fungicides

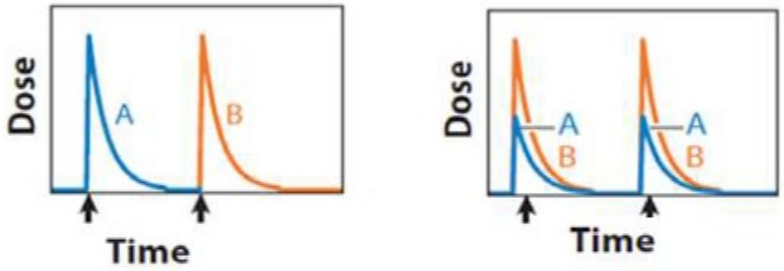
Plant Pathology. Manuscript ID is PP-19-223.

.DMI mutation data, 2012 & 2013, from 'SDHI LINK' project 2010-2013, HGCA 3517, 'Improved tools to rationalise and support stewardship programmes for SDHI fungicides to control cereal diseases in the UK', from sites in Herefordshire and Perth.

.SDH mutation data, 2016, from AHDB fungicide performance trials sited in Herefordshire, Cardigan and Hampshire.

Gaps in knowledge

Mix or alternate?



Why choose – do both!

Mixtures compared to alternation ..... selection			
reduce	No-difference	increase	Total
4	1	2	7

van den Bosch *et al*. 2014. *Annual Review Phytopathology*

Known Unknown: Protectant vis curative

- Fungicide resistance guidelines previously discouraged curative / eradicant use. Logic is if you are treating a large population you are likely to have many survivors that may be less sensitive.
- But this is unproven – a very small population with one fit survivor which could multiply rapidly is likely to be equally dangerous
- But pragmatically, protectant use offers you more choice of fungicides so is likely to be useful for that reason.

How will we retain efficacy in new and existing chemistry?

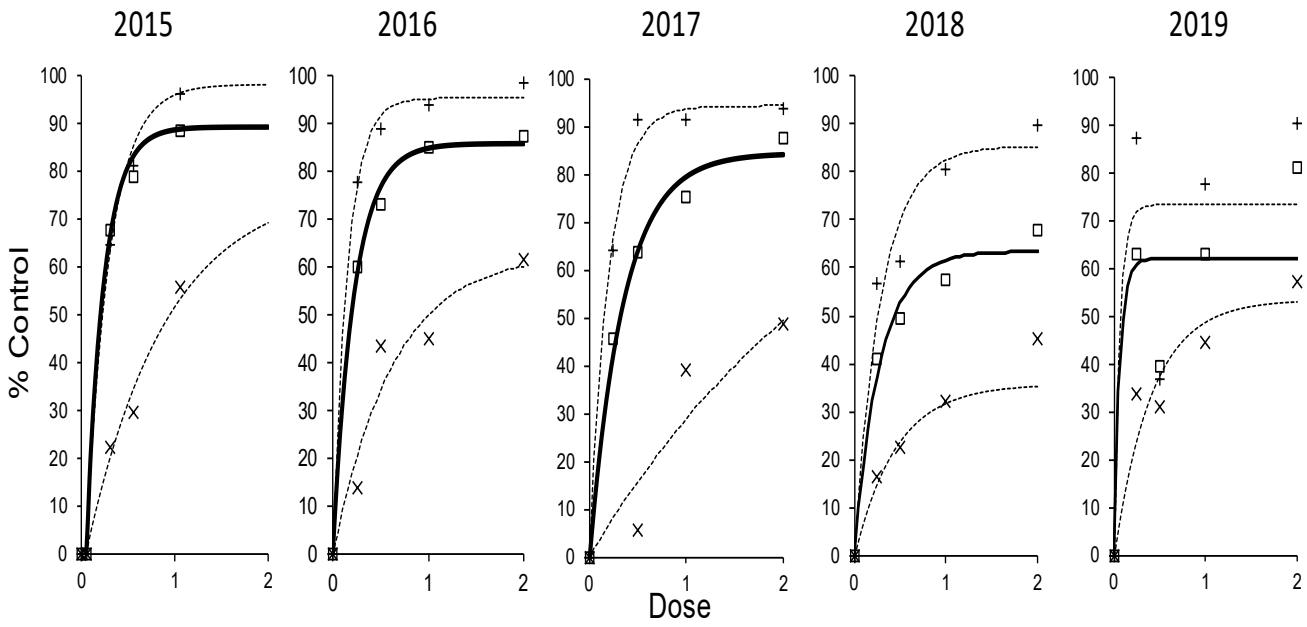
- Maximise use of low risk (multisite) fungicides as mixture partners
- Use minimum effective doses and balanced mixtures
- Limit use and alternate where possible
- If multiple applications of single-site fungicides are needed:-
- Limiting number of treatments of a MoA is a simple, practical message
- But may be unnecessarily restrictive or counterproductive (i.e. for multisites)
- Limiting by total dose may be effective and allow more flexibility
- Experimental evidence being obtained

Case study 1: Wheat / Septoria

- History of high yielding but susceptible varieties
- Multiple applications of limited number of chemical groups

- Resistance to QoIs since 2003
- Declines in azole sensitivity
- Issues with SDHIs emerging 2018 and 2019
- New chemistry is exciting but also needs protecting

SDHI emerging issues

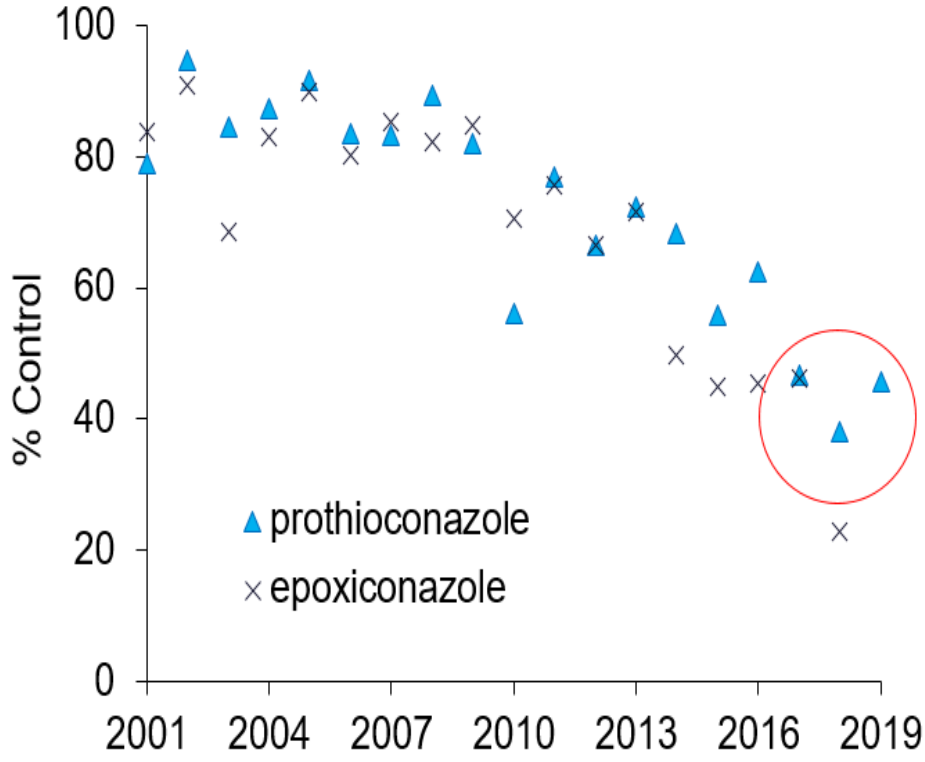


Strains less sensitive to SDHIs (e.g. T79N and N86S) now widely present in populations

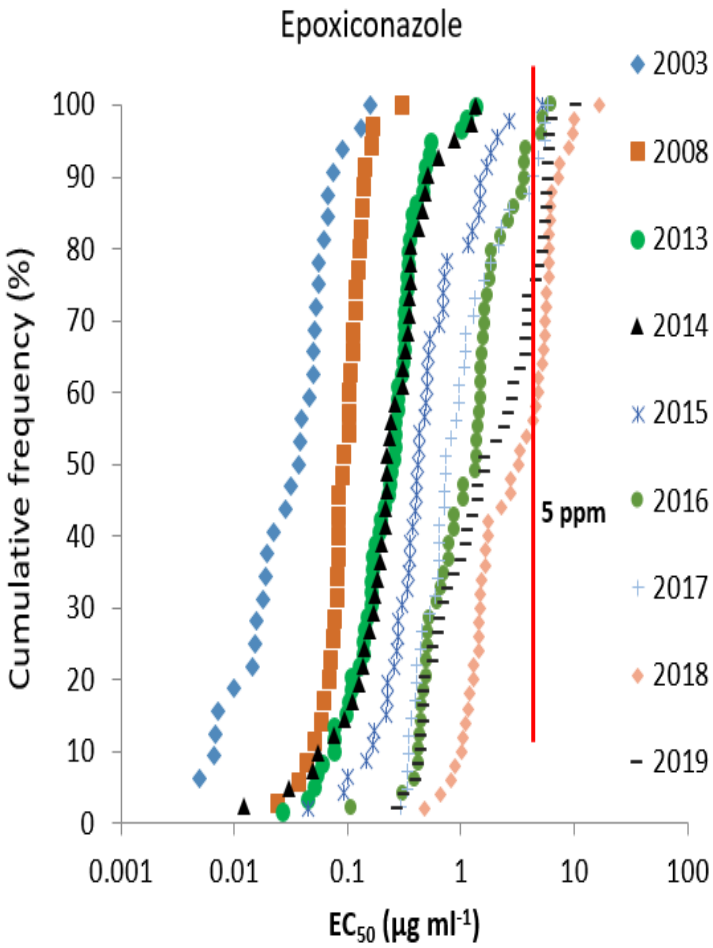
H152R overwintered at Rothamsted site

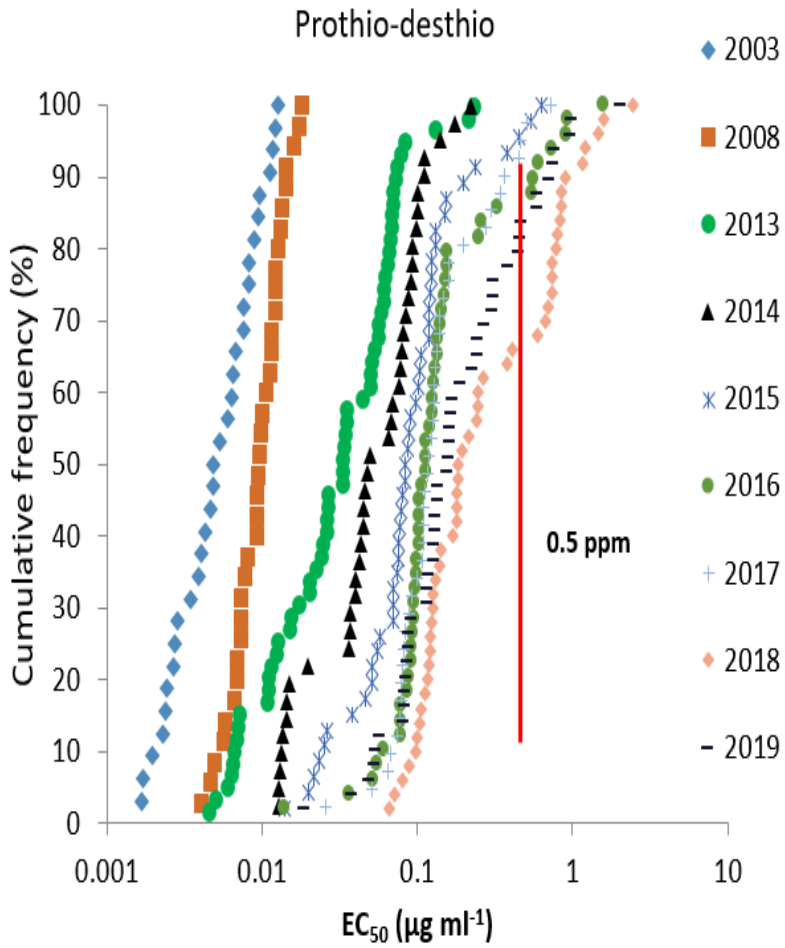
Azole efficacy on septoria tritici (2001–19)

Protectant activity at full rate



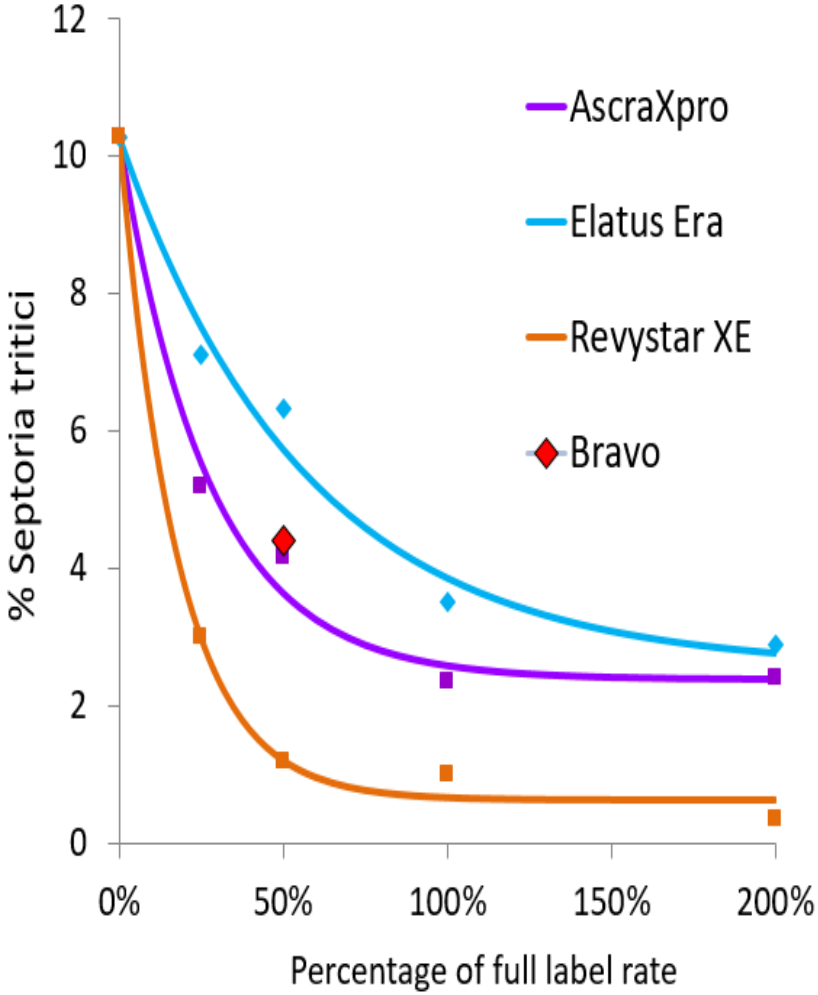
Rothamsted early season monitoring 2019

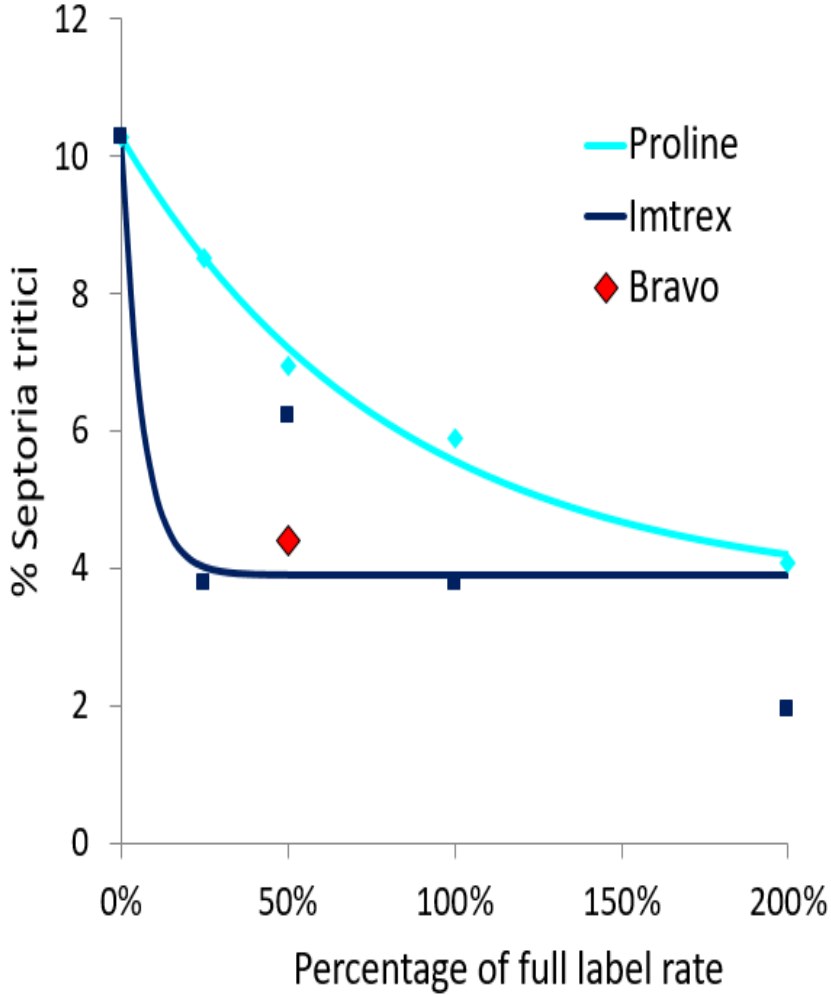




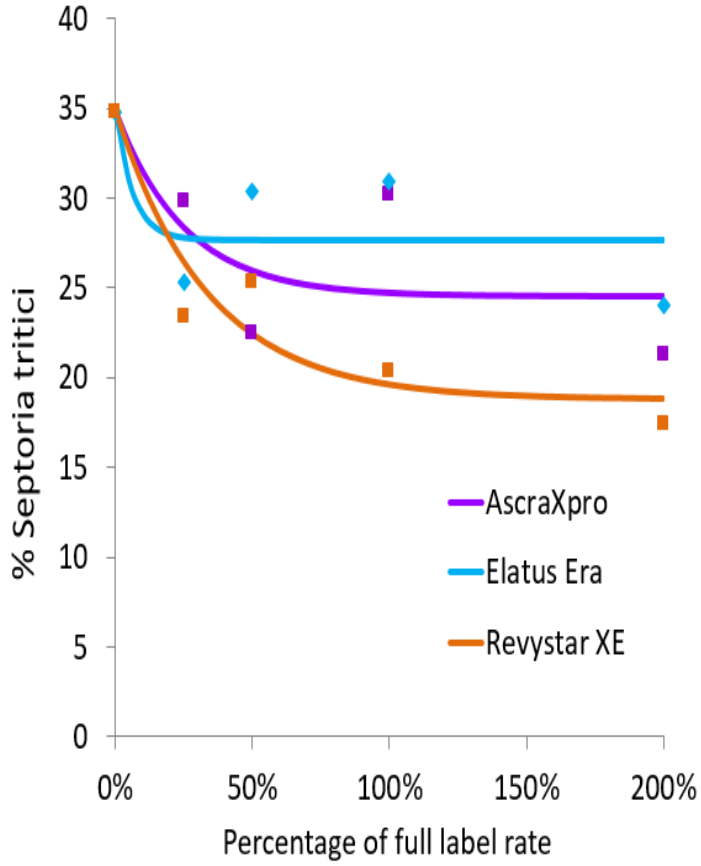
SRDP Farm Advisory Service

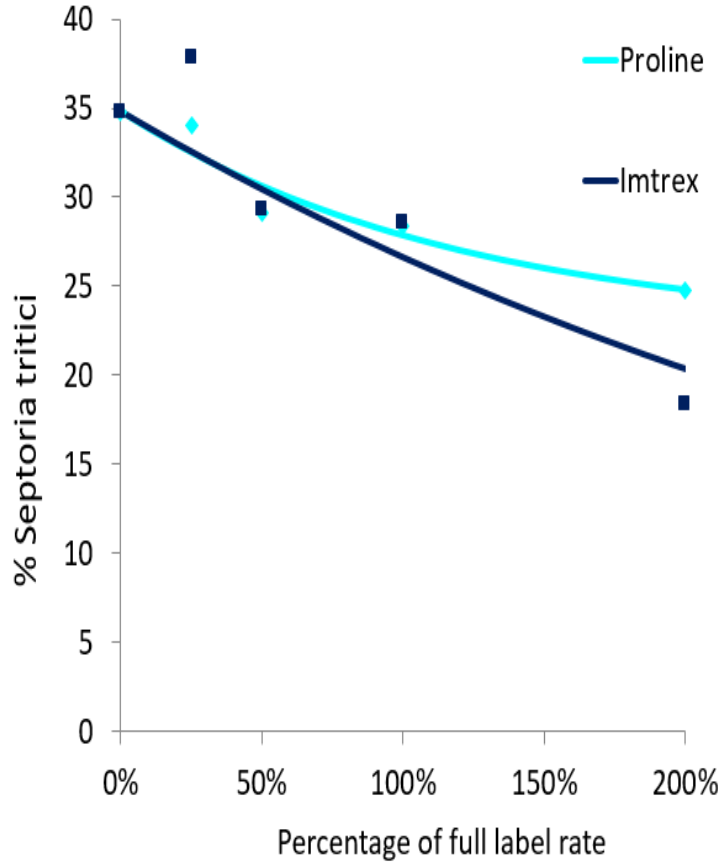
Septoria protectant activity 2019 (5 trials)





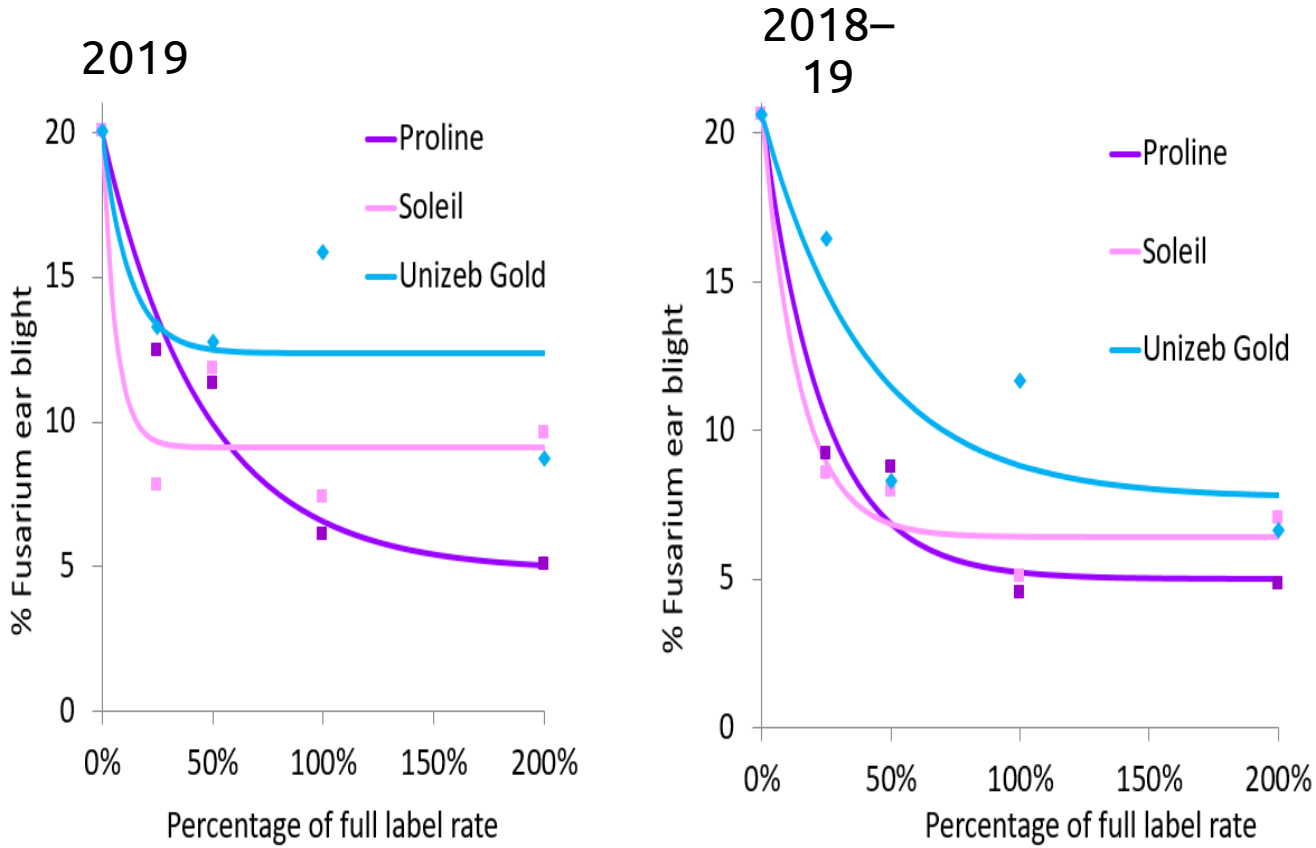
Septoria curative activity 2019 (2 trials)





Fusarium trials (inoculated)

Zyatt (near Mansfield, Nottinghamshire)



Soleil = tebuconazole + bromuconazole, Unizeb Gold = Mancozeb

Note: Mancozeb doesn't seem to control DON mycotoxin levels

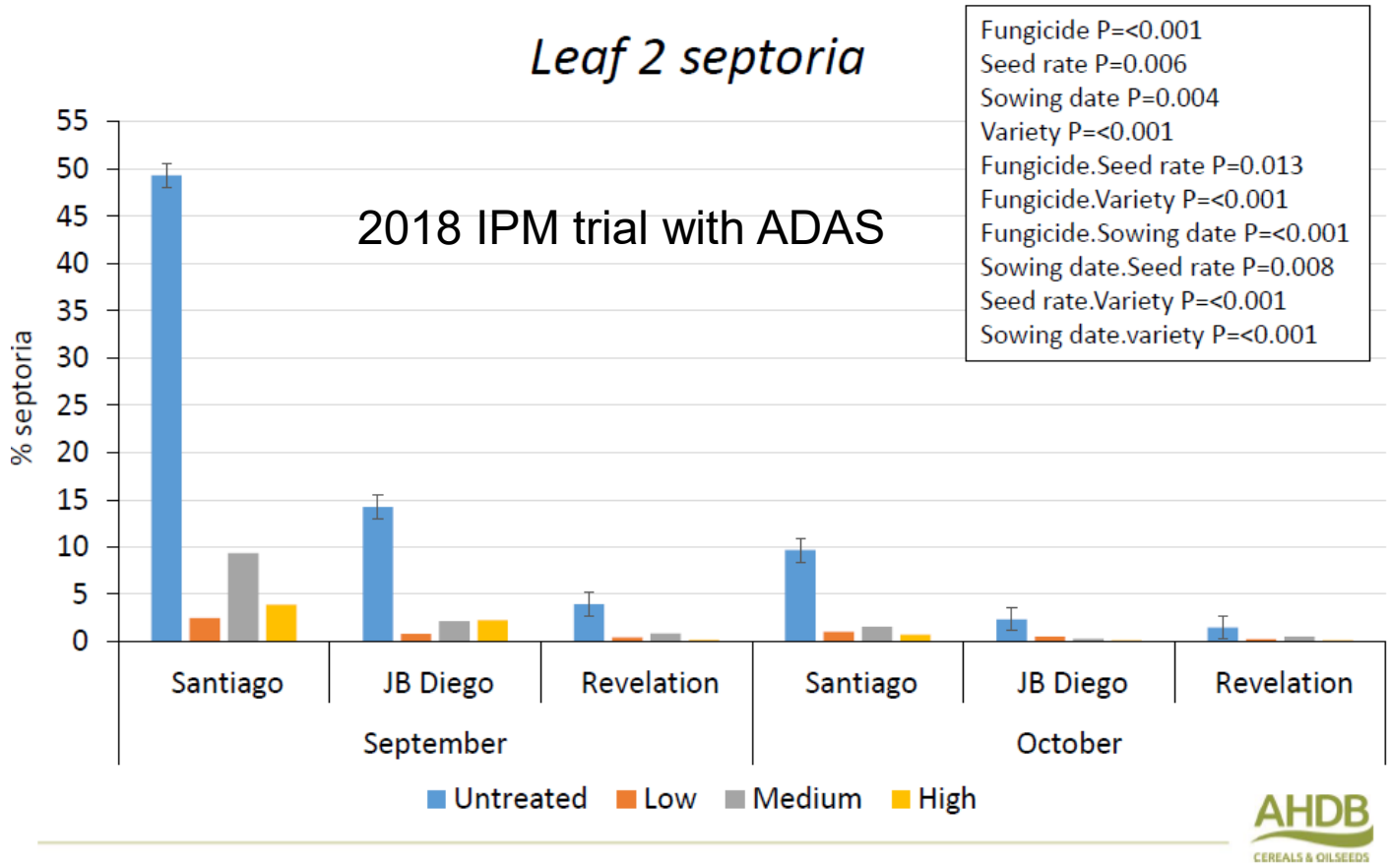
Wheat programmes – what do we **really** need?

- T minus – autumn or winter clean up
- T0 – early rust protection
- **T1 – stem-base disease and protection of yield important leaves**
- T1.5 – protection of leaf 2 is gap between T1 and T2 is stretched
- **T2 – protection of yield important flag**
- T3 – continued green leaf retention and protection from ear diseases
- T4 – continued ear disease protection

- Can we reduce use of more marginal sprays?

Opportunity: Valuing varietal resistance

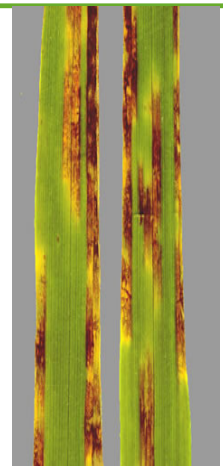
Disease assessment T2 + 3-4 weeks
18th June



	T0	T1	T2	T3
Late sown	x	Azole plus CTL	Range of SDHI/azole options plus alternative multisite	Alternate azole plus multisite
Resistant variety	x	Azole plus CTL	Range of SDHI/azole options plus alternative multisite	Alternate azole plus multisite
Early drilled	? Maximise CTL / minimise azole	Azole plus SDHI plus CTL	Try new chemistry plus alternative multisite	Alternate azole plus multisite
Susceptible variety	?Maximise CTL / minimise azole	Azole plus SDHI plus CTL	Try new chemistry plus alternative multisite	Alternate azole plus multisite
2nd wheat / eyespot risk	x	Azole plus SDHI plus CTL	Top rank products plus alternative multisite	Alternate azole plus multisite
Yellow rust scenario	Maximise strob / minimise and alternate azole / use CTL	Azole plus SDHI plus CTL (increase azole or add strob)	Maximise azole / use top rank mixture products plus multisite	Two-way azole mix plus multisite

Case study 2: Barley

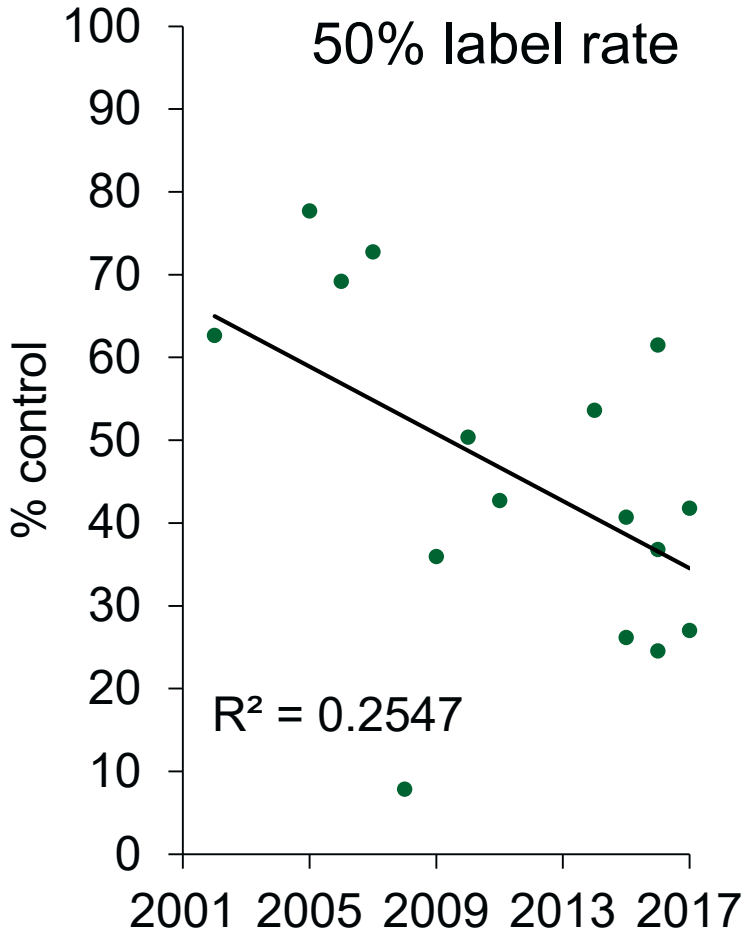
- Multiple disease targets
- Greater number of active groups
- Lower inputs
- History of slow uptake of more disease resistant varieties
- Issues with net blotch, mildew and rhynchosporium

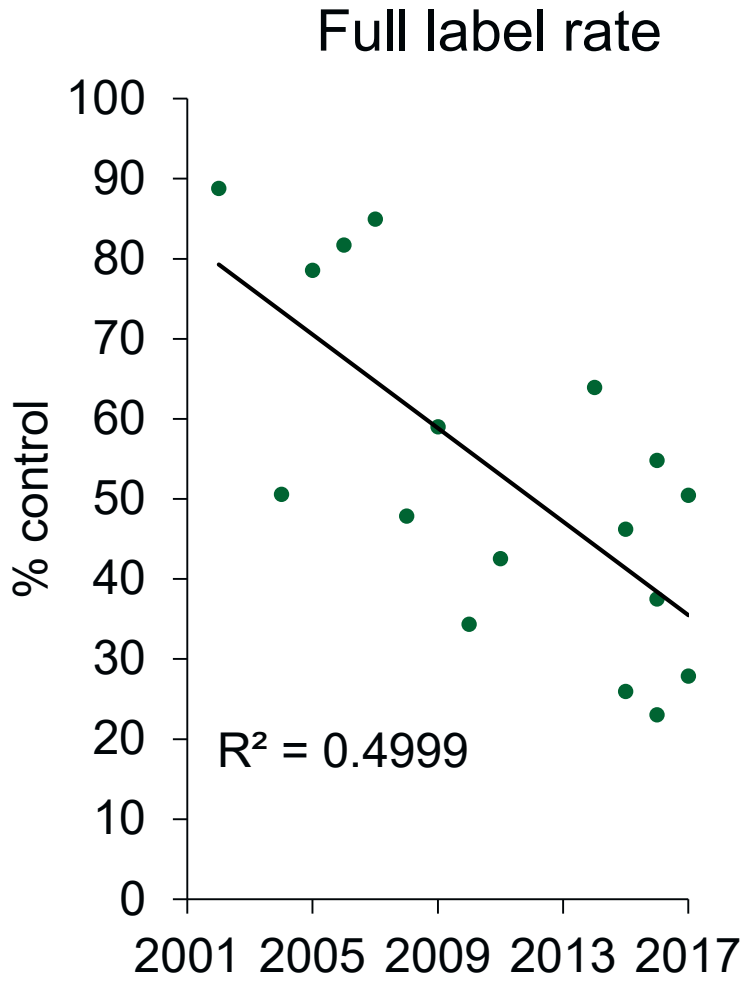


Ramularia – evolving picture

- QoI resistance since 2002
- MBC resistance (2 forms)
- Emerging issue with SDHIs 2014
- Field failures with azoles and SDHIs
- 2017 Fall off in field performance

Declines in QoI (strobilurin) efficacy on Rhynchosporium (2001 – 2017)

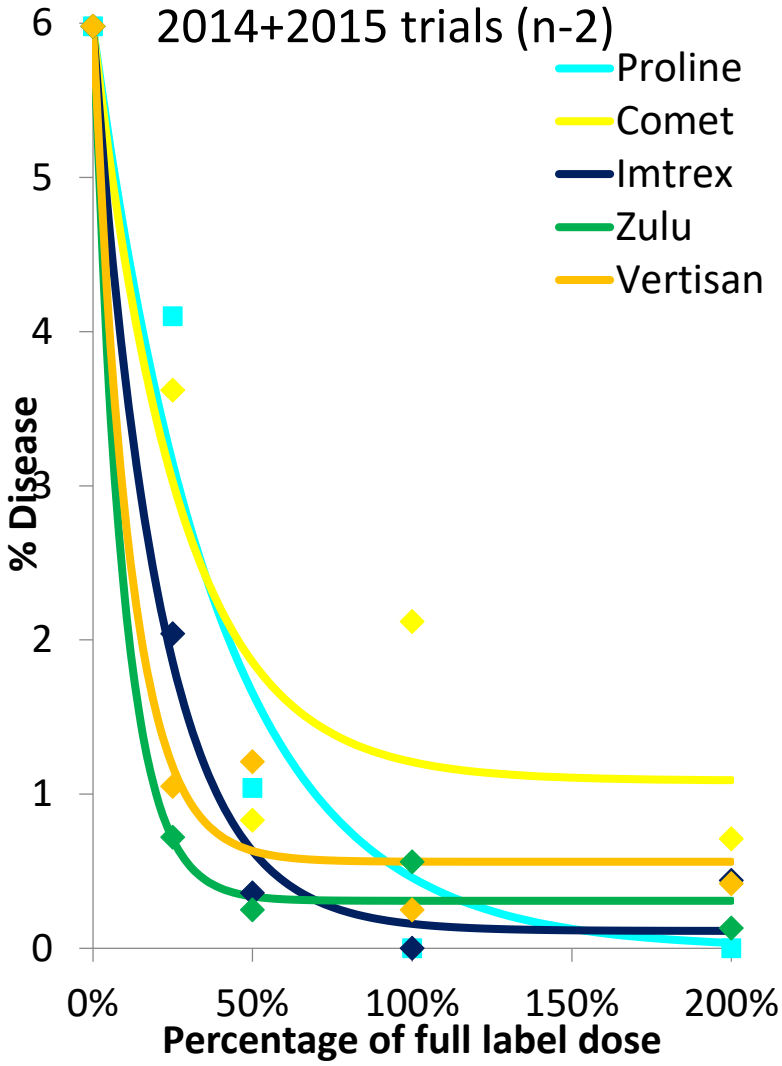


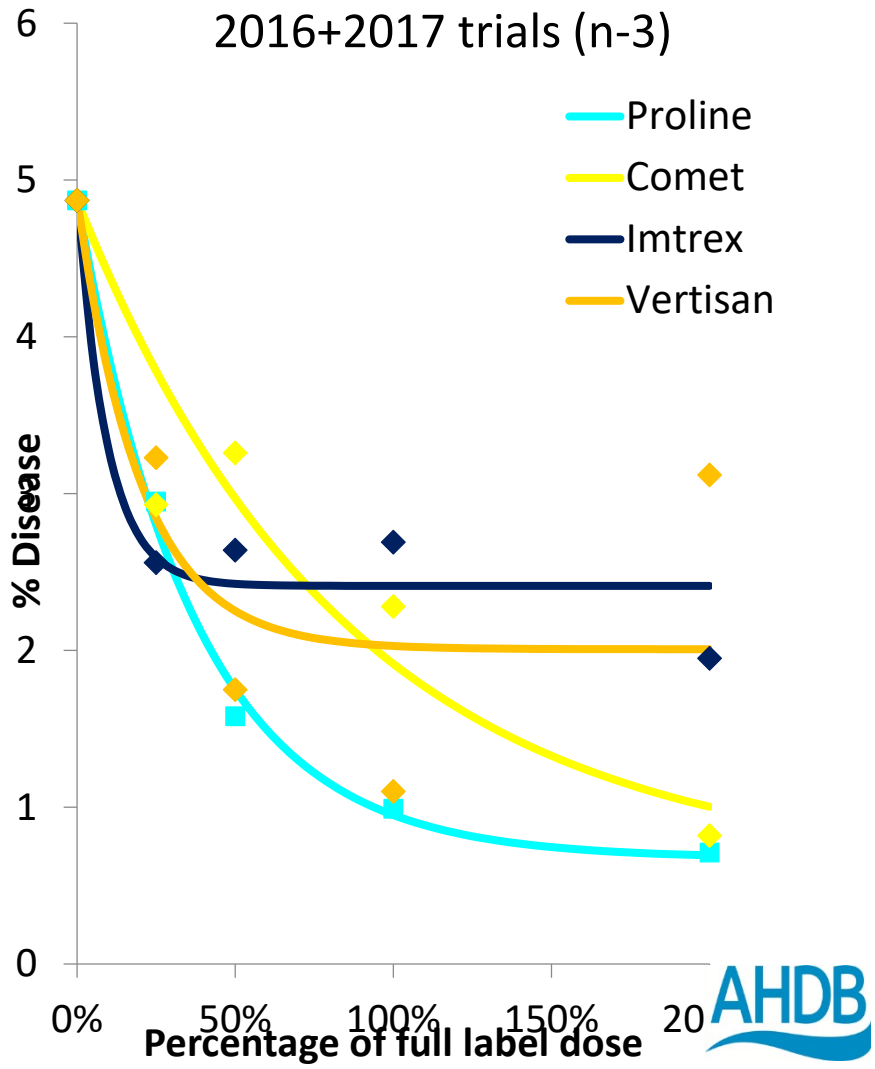


Data based on efficacy of Comet (pyraclostrobin)

Net blotch - changes in efficacy in recent seasons

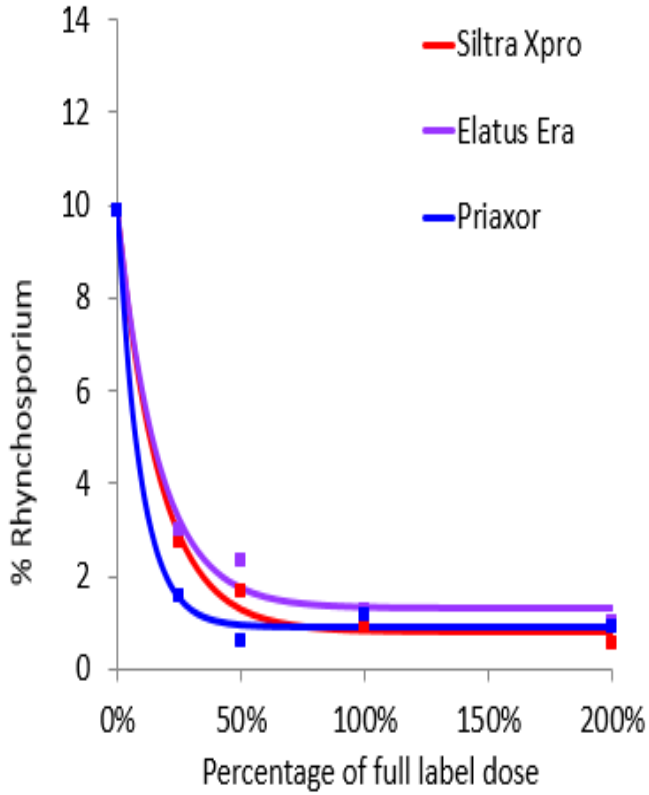
Mixture products still work well

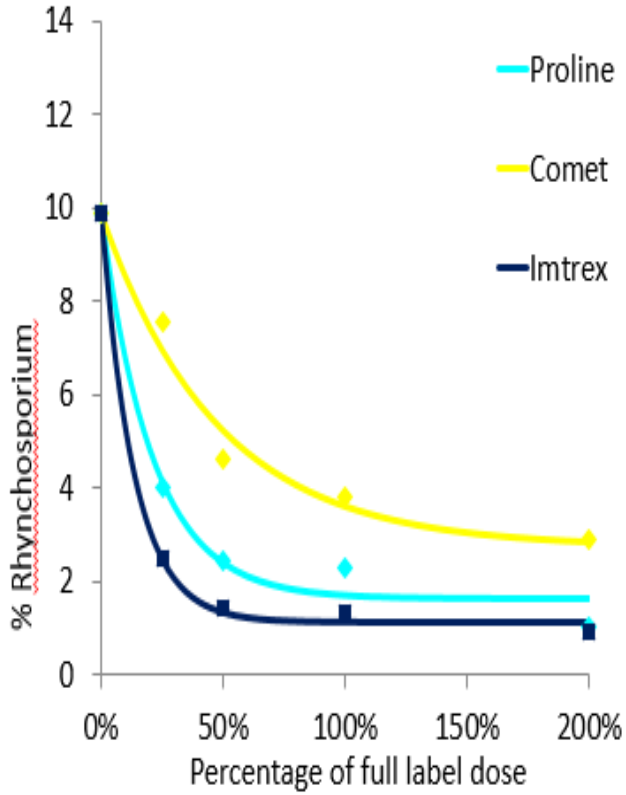




Rhynchosporium 2017–19 (8 trials)

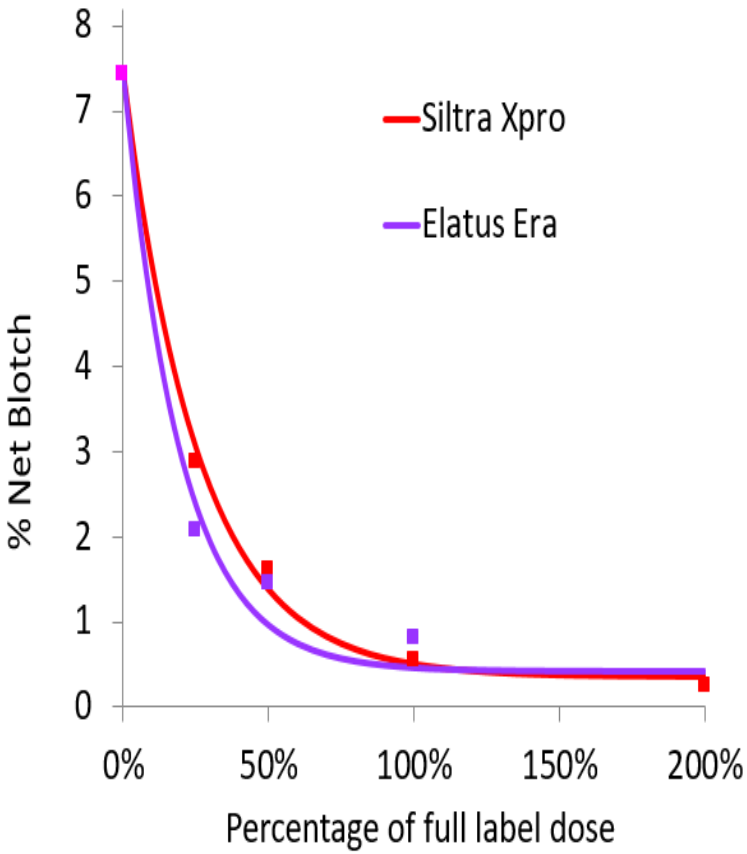
(protectant activity)

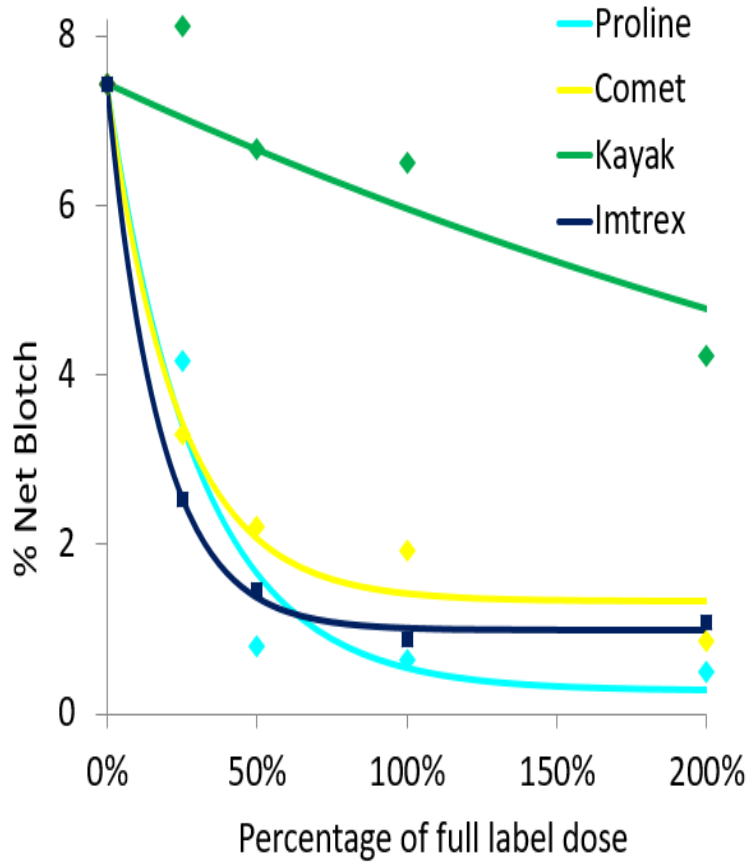




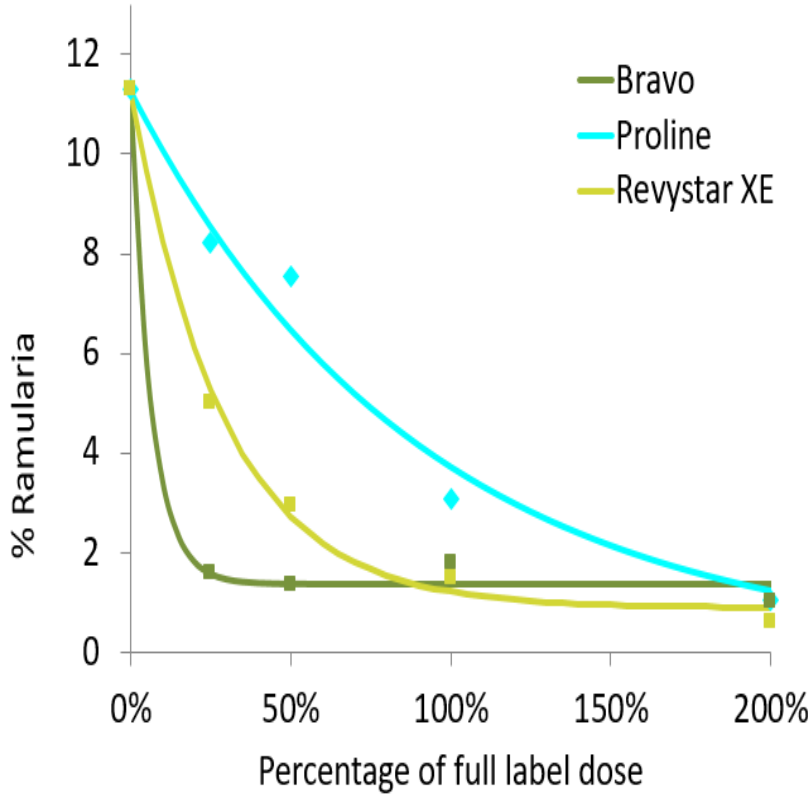
Priaxor = fluxapyroxad + pyraclostrobin

Net blotch protectant 2017–19 (4 trials)





Ramularia 2019 (2 sites)



Ramularia – a lesson in ‘how not to’

- Varieties to date have been weak so reliance on fungicides
- End user (malting) preference for consistency - majority of area often a single variety
- Fungicide resistance developments have changed the game

Ramularia – current advice

- Varietal ratings for ramularia withdrawn
- Breeding solutions are a longer game
- Use multisite chlorothalonil to manage ramularia risk at T1 and T2 (until 20th May 2020)
- Residual efficacy in prothioconazole
- Revystar XE efficacy sits between CTL and prothioconazole
- Folpet, biostimulants / micronutrients may play greater role
- Minimise crop stresses

Advice should be centred on efficient and targeted use

Understanding principles of fungicide use

- Manage crop to maximise grain number and potential grain size
- Early T1 sprays retain healthy tillers hence more ears where disease pressure threatens
- WB higher risk of early disease. SB lower risk at T1 and move to more resistant SB varieties gives scope to reduce T1 input
- A T2 application at GS49 gives sufficient protection of canopy post-anthesis to ensure grains fill to their storage capacity
- Later sprays (post T2) don't yield and could be omitted from recommendations

Barley programmes - strategic planning

	T0	T1	T2	T3
Winter barley Susceptible	X	CTL + mid dose azole + SDHI mix	Alternate azole / Switch to other multisite	X
Winter barley Resistant variety	X	CTL + low dose azole + strob mix	Switch to other multisite	X
Spring barley Susceptible variety	X	Low dose option in wet year and if disease present	Switch to other multisite PTZ + SDHI	X
Spring barley Resistant	X	CTL* (or nothing if late crop)	Switch to other multisite PTZ + SDHI	X
Spring barley High risk ramularia	X	CTL*	Switch to other multisite Try Revystar XE	X

CTL* - many spring barley crops may not reach mid tillering /T1 by 20th May and stock must be disposed of by then

Opportunity: Understand barriers to uptake

Co-construct anti-resistance strategies

Perception	Acceptable options
Increased uptake of IPM too complex	Increased varietal resistance React to weather, tillage and sow date
Not economic to reduce inputs	Keep inputs high but use mixtures and alternations Reduce use of marginal T0, T1.5 and T4 sprays Reduce use of high risk fungicides Increase use of lower risk / multisites
Fungicide resistance not important / not my problem	Label guidance Label requirements Statutory measures Public good for public money

Protecting products

- Do everything to reduce risk….rotation, variety, certified seed, sow date, monitoring, surveillance, crop walking, tailored sprays
- Value varietal resistance
- Don’t play fast and loose with new tools
- Take the risk of resistance in existing chemistry seriously
- Stick to guidelines and, obviously, to statutory limits

- Keep abreast of developments and follow the best technical advice
- Everyone wants new twists and clever pitches but this can leave individuals dangerously exposed and puts our whole industry at risk …. there are genuine win: wins.

SRUC

Fungicide Futures