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Fungicide performance in wheat, barley and oilseed rape (2015–18)

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CONTENTS

1. Abstract

Across the four harvest seasons (2015–18), the efficacy of fungicides was tested against the main pathogens of wheat, barley and oilseed rape. The diseases targeted were those with the highest incidence and/or greatest potential economic impact for growers.

The fungicides included new active substances, new mixtures of existing chemistry and treatments established as current commercial standards. A wide range of modes of action were trialled, including azoles, succinate de-hydrogenase inhibitors (SDHIs), strobilurins and multi-site inhibitors. Fungicides were tested at a range of application rates against each pathogen to enable creation of dose response curves. These curves allow comparisons to be drawn between treatments for disease control and yield, and for shifts in efficacy to be monitored over several years. During the course of the project, some new products have been registered for use and the data has been made public at the time of commercial release. Others are yet to be registered and, as such, the data from these treatments is not included in this report.

In wheat, fungicide treatments were tested by applying single applications at rates, ranging from quarter to double dose on septoria tritici, yellow rust, brown rust and head blight. Single applications were also used to test the effect of fungicides against rhynchosporium, net blotch, ramularia and powdery mildew in barley. For oilseed rape, phoma leaf spot/stem canker and light leaf spot were tested using a two spray programme. Efficacy against sclerotinia stem rot was evaluated using a single fungicide application at early to mid-flowering.

SDHI-based mixtures, including those registered during the project (Ascra Xpro and Elatus Era), were the most effective treatments against septoria tritici, with strong protectant and curative activity. Bravo (chlorothalonil) consistently demonstrated good levels of protection across the sites, showing activity typically greater than the triazoles and equivalent to the SDHIs. Across this project and years previous, straight triazoles, SDHIs and mixed treatments showed a decline in activity against septoria tritici. Imtrex (fluxapyroxad) demonstrated consistent control of yellow rust. Although other treatments, such as Ignite (epoxiconazole), were more effective, these proved more variable between seasons. Similarly for brown rust, variation between the seasons was high and there were no consistent trends separating different classes of active substances (straight triazoles, straight SDHIs, mixtures), although Proline (prothioconazole) was less effective than other treatments, in the years it was tested.

In barley, Proline (prothioconazole) and the SDHI-azole mixtures, Elatus Era and Siltra Xpro (both containing prothioconazole), showed strong control of rhynchosporium, net blotch and powdery mildew. Priaxor (pyraclostrobin + fluxapyroxad) also displayed good activity against rhynchosporium and net blotch, whilst Cyflamid and Talius (specific mildewicides) controlled powdery mildew well.

Over the four years, the data collected on ramularia control was limited due to low-pressure seasons and the absence of disease. However, there were indications of changes in activity during this period of investigation, such that by 2018 only Bravo (chlorothalonil) and mixtures containing chlorothalonil had efficacy on ramularia.

Both azole and non-azole products had activity against phoma leaf spot/stem canker and light leaf spot. Filan and Proline all controlled phoma leaf spot/stem canker, with Cirkon and Orius 20EW appearing less effective overall. Plover was tested against phoma in one year only, and gave equivalent or slightly lower levels of control compared with Proline. Despite this difference in disease control, yields were generally similar. Azoles (Proline and Orius 20EW/Orius P) and non-azoles (Pictor) were found to be effective against light leaf spot on oilseed rape. Refinzar was also effective, however approval was revoked after November 2018. Filan, Pictor, Proline and Amistar were all effective against sclerotinia stem rot on oilseed rape.

The data described in this report, generated over the 2015–18 harvest seasons, provide information of the relative efficacy of different fungicide treatments, with a particular focus on their active substances. This can be used by growers and agronomists to generate robust fungicide programmes targeting specific disease threats and to evaluate shifts in treatment efficacy over time.

2. Introduction

Robust disease control strategies are an important component of the commercial production of wheat, barley and oilseed rape as they can have a significant impact on yield and profitability. Although cultural approaches, including crop rotation, drilling dates and selection of resistant varieties are important for integrated pest management (IPM) strategies and disease control, fungicides remain a key aspect of most disease management programmes.

Fungicides with broad spectrum activity, such as the triazoles and succinate de-hydrogenase inhibitors (SDHIs) form the basis of most current commercial programmes for disease management in UK arable crops. However, the activity of the triazoles against a number of key diseases has declined: a key example is *Zymoseptoria tritici*, which has accumulated numerous mutations in the *CYP51* target site enzyme, to become increasingly less sensitive (Blake *et al.*, 2017). The industry has recognised that care must be taken to protect the SDHIs against the same fate and as such, it is recommended that SDHIs should only be applied a maximum of twice in the fungicide programme and either as a co-formulation or tank mixed with an effective alternative mode of action. Strobilurins still give useful control of several diseases across the three crops, particularly rusts. Multi-site acting fungicides, such as chlorothalonil, can add usefully to efficacy on several diseases and are essential in reducing the risk of resistance development against existing and new chemistry.

The data summarised here report the efficacy of individual fungicide products to control disease and protect yield, using dose-response curves to draw comparisons between treatments and to monitor shifts in activity over several years. The full dataset from this project, spanning the 2015 to 2018 harvest seasons, can be found on the AHDB website (www.cereals.ahdb.org.uk).

3. Materials and methods

3.1. Wheat

3.1.1. Site selection and establishment

The experiments were conducted over four harvest years (2015 – 2018) across the UK to test fungicide performance against three foliar diseases of wheat: septoria tritici, yellow rust, brown rust and head blight. These diseases were assessed in nine or ten trials across seven sites each year, selected for high disease risk and using susceptible cultivars to create high disease pressure for each of the target diseases (Table 1).

Table 1: Site numbers, locations, harvest years, cultivars and target diseases of wheat trials

Site number	Location	Harvest year	Variety	Disease
1	ADAS, Rosemaund, Herefordshire	2015	Consort	Septoria tritici
2a	NIAB, Sutton Scotney, Hampshire	2015	KWS Cashel	Septoria tritici
2b	NIAB, Sutton Scotney, Hampshire	2015	KWS Cashel	Septoria tritici
3a	SRUC, Balgonie, Fife	2015	Consort	Septoria tritici
3b	SRUC, Balgonie, Fife	2015	Consort	Septoria tritici
4	ADAS, Terrington, Norfolk	2015	Oakley	Yellow rust
5	NIAB, Duxford, Cambridgeshire	2015	Crusoe	Brown rust
6	ADAS, Gleadthorpe, Nottingham	2015	Grafton	Head blight
7	Teagasc, Carlow	2015	KWS Lumos	Septoria tritici
8	ADAS, Rosemaund, Herefordshire	2016	Consort	Septoria tritici
9a	NIAB, Sutton Scotney, Hampshire	2016	Dickens	Septoria tritici
9b	NIAB, Sutton Scotney, Hampshire	2016	Dickens	Septoria tritici
10a	SRUC, Balgonie, Fife	2016	Consort	Septoria tritici
10b	SRUC, Balgonie, Fife	2016	Consort	Septoria tritici
11	ADAS, Terrington, Norfolk	2016	Oakley	Yellow rust
12	NIAB, Duxford, Cambridgeshire	2016	Crusoe	Brown rust
13	ADAS, Gleadthorpe, Nottingham	2016	Grafton	Head blight
14	Teagasc, Carlow	2016	KWS Lumos	Septoria tritici
15	ADAS, Cardigan	2016	KWS Santiago	Septoria tritici
16	ADAS, Rosemaund, Herefordshire	2017	KWS Santiago	Septoria tritici
17a	NIAB, Sutton Scotney, Hampshire	2017	Dickens	Septoria tritici
17b	NIAB, Sutton Scotney, Hampshire	2017	Dickens	Septoria tritici
18a	SRUC, Balgonie, Fife	2017	Consort	Septoria tritici
18b	SRUC, Balgonie, Fife	2017	Consort	Septoria tritici

19	ADAS, Terrington, Norfolk	2017	Reflection	Yellow rust
20	NIAB, Duxford, Cambridgeshire	2017	Crusoe	Brown rust
21	ADAS, Gleadthorpe, Nottingham	2017	Grafton	Head blight
22	Teagasc, Carlow	2017	KWS Lumos	Septoria tritici
23	ADAS, Cardigan	2017	KWS Santiago	Septoria tritici
24	ADAS, Rosemaund, Herefordshire	2018	KWS Santiago	Septoria tritici
25a	NIAB, Sutton Scotney, Hampshire	2018	Dickens	Septoria tritici
25b	NIAB, Sutton Scotney, Hampshire	2018	Dickens	Septoria tritici
26a	SRUC, Balgonie, Fife	2018	KWS Santiago	Septoria tritici
26b	SRUC, Balgonie, Fife	2018	KWS Santiago	Septoria tritici
27	ADAS, Terrington, Norfolk	2018	Reflection	Yellow rust
28	NIAB, Duxford, Cambridgeshire	2018	Crusoe	Brown rust
29	ADAS, Gleadthorpe, Nottingham	2018	Grafton	Head blight
30	Teagasc, Carlow	2018	KWS Lumos	Septoria tritici
31	ADAS, Cardigan	2018	KWS Barrel	Septoria tritici

Each of the trials sites had at least a one year break from cereals to minimise the risk of take-all increasing variability across the trial plots or interfering with fungicide yield responses. Soil samples from each site were analysed for pH, nutrient content and soil texture. When appropriate sites were located, the trials were drilled at the correct seed rate for the locality and soil type using a suitable drill (e.g. Øyjord). The plot size in each trial was in the range of 20 – 60 m^2 for all sites except those conducting head blight trials, which were 4 m^2. Good farm practice was followed for all inputs (with the exception of fungicides) to ensure, as far as possible, that the trials were not affected by nutrient deficiencies or pest and weed infestations. Sites 2, 3, 9, 10, 17, 18, 25 and 26 hosted two trials each, with a T1 or T2 application of treatments noted in Table 1 as (a) and (b).

Brown rust trials were inoculated to ensure products were effectively tested against a disease which can otherwise be spasmodic. In 2015 and 2016, this was done by infecting pot-grown plants of the same cultivar as the trial with a brown rust race virulent on that cultivar. In 2015, three actively sporulating 'transplants' consisting of approximately 15 four-week old seedlings were planted into each plot with an even distribution and watered until they had established. In 2016, four transplants were used. In 2017 and 2018, puffing a spore-talc mixture onto plants was used to inoculate the plots four to six weeks before the planned treatments and was repeated as necessary to ensure disease establishment.

The head blight trials were inoculated with *Fusarium graminearum and F. culmorum*, 1 to 2 days after fungicide treatment, when 50 to 75% of ears were showing some anthers. Inoculum of 250,000 to 400,000 spores/ml was sprayed in early evening at a rate of 220 l/ha directly onto the central

1 m x 2 m plot area. Misting irrigation was turned off at midday prior to inoculation to allow time for excess water to dissipate to prevent inoculum running off, and restarted on the morning after inoculation.

All other trials relied on natural infection.

3.1.2. Experiment design

A randomised block design incorporating standard randomisation of treatments within each replication was used. Each trial incorporated between 18 and 67 treatments with three replicates.

3.1.3. Fungicide treatments

Fungicides were applied using hand-held plot spraying equipment, with 200 to 300 kPa of pressure to produce a medium quality spray.

A variety of fungicides were tested to determine their ability to control disease, with dose response treatments of quarter, half, full and double recommended label rates. Double dose treatments are not permitted for on-farm crops and were used only to enable accurate dose-response curve fitting. Double dose treatments, and those not yet commercially available were subject to an experimental permit and grain was destroyed at harvest. Full label rates are shown in table 2 and all doses stated are a percentage of these values.

In each season, the number of products that could be tested alongside core treatments was limited. Therefore, products included in the trials were those containing a new active substance, those containing a recently approved active substance/s or established “commercial standards” to compare against their baseline performance. Where a new active substance was only available commercially as a formulated mixture, where possible, the relevant mixture partner/s were also included in the trials to determine spectrum of activity and/or any synergy. Spectrum of activity was used to determine the target diseases against which each new product should be tested. Since the start of the project, the products Ascra Xpro, Elatus Era and Priaxor have become commercially available.

Product efficacy on septoria tritici was tested in 7 trials in 2015, and 8 trials in all other seasons. There was one trial per year for each of the rusts and head blight (Table 1).

Table 2: Full label rates (l/ha), and active substance (g/ha), for products tested for the control of one or more diseases of wheat between 2015 and 2018.

Product tested	**Full label rate l/ha**	**Active substance (a.s.) g/ha at full label rate**
Adexar	2.0	epoxiconazole 125g + fluxapyroxad 125g
Ascra Xpro	1.5	bixafen 97.5g + prothioconazole 195g + fluopyram 97.5g
Aviator Xpro	1.25	prothioconazole 200g + bixafen 93.75g
Bravo	2.0	chlorothalonil 1000g
Caramba 90	1.0	metconazole 90g
Comet 200	1.25	pyraclostrobin 250g
Elatus Era	1.0	benzovindiflupyr 75g + prothioconazole 150g
Folicur	1.0	tebuconazole 250g
Ignite/Bassoon **	1.5	epoxiconazole 124.5g
Imtrex	2.0	fluxapyroxad 125 g
Keystone	1.0	epoxiconazole 99g + isopyrazam 125g
Librax	2.0	fluxapyroxad 125g + metconazole 90g
Priaxor	1.5	fluxapyroxad 112.5 + pyraclostrobin 225g
Proline*	0.72	prothioconazole 198g
Soleil	1.2	bromuconazole 200.4g + tebuconazole 128.4g
Unizeb Gold	3.0	mancozeb 1500g
Vertisan	1.5	penthiopyrad 300g
Vertisan & Ignite	1.5 + 1.5	penthiopyrad 300g + epoxiconazole 124.5g

*Proline and Proline275 were considered comparable as they both delivered more or less the same loading of a.s. at full label rate. This was a concentration rather than a formulation change.

**Bassoon and Ignite both contain epoxiconazole as a single a.s. at the same concentration, and were considered comparable. For consistency Ignite is used throughout this report, although from time to time the actual product used may have been Bassoon. Similarly, Caramba 90 and Sunorg Pro both contain metconazole at the same concentration and Caramba 90 has been used throughout this report for consistency.

Septoria tritici dose-response trials

Trials were set up using the same treatment list across all the sites, with the exception of Teagasc, Carlow where there were some minor differences, although the majority of treatments were the same as the other sites in each year.

NIAB, Sutton Scotney and SRUC, Fife both held two trials per year, each testing the effectiveness of nine treatments at the T1 (GS32) timing or T2 timing (GS39). Three further sites hosted a single trial: Carlow applied fungicides at GS37, whilst at Rosemaund and Cardigan, fungicide applications were timed to follow a period of wet weather, so as to increase the probability of attaining curative information for the dose response.

Bravo was applied in each trial at half rate only as a standard to compare with the other treatments and to help determine if timings were largely protectant or curative.

Yellow rust trials

Yellow rust control was evaluated near Terrington in Norfolk at sites 4, 11, 19 and 27. Ten fungicides, applied at GS32 to 33, were tested each year at quarter, half, full and double rates.

Brown rust trials

Brown rust control was tested each year near Cambridge (trial numbers 5, 12, 20 and 28). Five fungicides, each at four application rates (quarter, half, full and double) were applied at GS37 to GS39 to determine the effects of treatment and dose on brown rust.

Head blight trials

Each year, trials at ADAS Gleadthorpe, near Nottingham, tested the effectiveness of four fungicides, applied at GS63 to 65 (trial numbers 6, 13, 21 and 29). Each year, four dose rates (quarter, half, full and double) were used to measure control of head blight.

3.1.4. Assessments and records

Assessments of leaf disease and green leaf area

Tillers were randomly selected and foliar disease assessments were carried out by estimating the percentage of green area and the percentage of each leaf affected by disease (including any necrosis and chlorosis associated with the disease).

At all sites except Gleadthorpe, disease assessments took place to calculate mean scores for each foliar disease present (including non-target diseases) and for green leaf area for each individual leaf layer, excluding senesced leaf layers.

Assessment timings:

1. Prior to fungicide treatment applications, a background assessment was conducted by assessing 40 plants at random across the trial area in all trials.
2. On two occasions after treatments were applied, full disease assessments were conducted by leaf layer and based on 10 shoots per plot. For septoria trials this was usually 3 and 6 weeks post treatment. Assessment timings were brought forward if the top two leaves on untreated plots had over 50% infection.

Seven to 14 days following each application timing, any observed effects attributable to phytotoxicity were recorded.

Assessments of ear diseases

At trials at Gleadthorpe, head blight was assessed every five days from day 7 to 27 post-inoculation, with percent incidence recorded. Percent severity was also recorded for 2015. From each plot, 200 wheat heads were collected for molecular analysis by qPCR to provide a quantitative determination of the main head blight pathogens present after the treatment and ELISA tests to identify any differences in deoxynivalenol mycotoxin as a result of treatment. Whitehead incidence was noted upon occurrence, along with the cause.

Assessment of stem-base diseases

To ensure stem-base diseases did not skew results, stem-base diseases were recorded on 25 randomly selected shoots at GS31 to 32 before any treatments had been applied (in septoria tritici and yellow rust trials). Incidence was recorded for any disease found and a severity score given for eyespot if seen. Stem-base disease was assessed again at GS75 by selecting 25 plants in every untreated plot and categorising any lesions into slight, moderate or severe. A full assessment of all plots was conducted if over 25% of stems had moderate or severe lesions or 10% had severe lesions of any disease.

Lodging

Plots were assessed for lodging prior to harvest. The percent area affected was recorded if lodging was present.

Yield

All plots in the septoria tritici and rust trials were harvested using a plot combine. Grain samples were taken to determine moisture content and for specific weight assessment. Yields were calculated at 85% dry matter. No yield measurements were taken on head blight trials.

Grain quality

Specific weight of grain was measured for each plot and adjusted to 85% dry matter for septoria tritici and rust trials only.

Agronomic records

Details of site, soil type and all other agrochemical inputs were recorded.

3.2. Barley

3.2.1. Site selection and establishment

The experiments ran over four harvest years (2015 – 2018) across the UK to test fungicide performance against three foliar diseases of winter barley: net blotch, powdery mildew and rhynchosporium, and ramularia in spring barley. There were seven sites each year (Table 3).

Sites were selected to represent a high risk scenario for the target diseases, based on prevailing environmental conditions and past history. Trials were drilled with susceptible cultivars at the correct seed rate for the locality and soil type. The size of the plots in each trial ranged from 20 to 60 m^2, typically 12 m x 2 m. Good farm practice was followed for all inputs (with the exception of fungicides) to ensure, as far as possible, that the trials were not affected by nutrient deficiencies or pest and weed infestations. Soil samples from each site were analysed for pH, nutrient content and soil texture. With the exception of net blotch, each of the trials sites had at least one year's break from cereals to minimise the risk of take-all or stem-base diseases interfering with fungicide efficacy data. All trials relied on natural infection.

Table 3: Site numbers, locations, harvest years, cultivars and target diseases in barley trials

Site number	**Location**	**Harvest year**	**Variety**	**Disease**
1	SRUC, Lanark	2015	Saffron	Rhynchosporium
2	SRUC, Midlothian	2015	Cassia	Powdery mildew
3	ADAS, Cardigan	2015	Saffron	Rhynchosporium
4	ADAS, High Mowthorpe, North Yorkshire	2015	Cassata	Net blotch
5	NIAB, Fakenham, Norfolk	2015	Cassata	Net blotch
6	SRUC, Midlothian	2015	Prestige	Ramularia
7	Teagasc, Carlow	2015	Quench	Rhynchosporium
8	SRUC, Lanark	2016	Saffron	Rhynchosporium
9	SRUC, Midlothian	2016	Cassia	Powdery mildew
10	ADAS, Cardigan	2016	Cassia	Rhynchosporium
11	ADAS, High Mowthorpe, North Yorkshire	2016	Cassata	Net blotch
12	NIAB, Fakenham, Norfolk	2016	Flagon	Net blotch
13	SRUC, Midlothian	2016	Quench	Ramularia
14	Teagasc, Carlow	2016	Cassia	Rhynchosporium
15	SRUC, Lanark	2017	Saffron	Rhynchosporium
16	SRUC, Midlothian	2017	Cassia	Powdery mildew
17	ADAS, Cardigan	2017	Cassia	Rhynchosporium
18	ADAS, High Mowthorpe, North Yorkshire	2017	Tower	Net blotch
19	NIAB, Fakenham, Norfolk	2017	Flagon	Net blotch
20	SRUC, Midlothian	2017	Fairing	Ramularia
21	Teagasc, Carlow	2017	Cassia	Rhynchosporium
22	SRUC, Lanark	2018	Saffron	Rhynchosporium
23	SRUC, Midlothian	2018	Cassata	Powdery mildew
24	ADAS, Cardigan	2018	Cassia	Rhynchosporium
25	ADAS, High Mowthorpe, North Yorkshire	2018	Tower	Net blotch
26	NIAB, Fakenham, Norfolk	2018	Flagon	Net blotch
27	SRUC, Midlothian	2018	Fairing	Ramularia
28	Teagasc, Carlow	2018	Cassia	Rhynchosporium

3.2.2. Experiment design

A randomised block design incorporating standard randomisation of treatments within each replication was used. Each trial incorporated 36 to 40 treatments, including an untreated control and each treatment was replicated three times.

3.2.3. Fungicide treatments

A variety of pre-registration and commercially available fungicides were tested each year to determine their efficacy and dose responses against the main foliar diseases. Fungicide doses (quarter, half, full and double) stated in this report are all expressed as a percentage of full label rates (Table 4). Double doses were used only to enable accurate dose-response curve fitting; the grain from these plots and those treated with pre-registration products were subject to experimental permits and were destroyed after harvest. Since the start of the project, Elatus Era and Priaxor have become commercially available and therefore data can be included.

A single application of each fungicide was applied in 200 to 300 litres water/ha using pressurised hand-held plot spraying equipment. A pressure of 200 to 300 kPa was used to produce a medium quality spray.

Table 4: Full label rates (l/ha), and active substance (g/ha), for products tested for the control of one or more diseases of barley between 2015 and 2018.

Product tested	Full label rate l/ha	Active substance (a.s.) g/ha at full label rate
Adexar	2.0	epoxiconazole 125g + fluxapyroxad 125g
Bravo	2.0	chlorothalonil 1000g
Comet 200	1.25	pyraclostrobin 250g
Cyflamid	0.5	cyflufenamid 25g
Elatus Era	1.0	benzovindiflupyr 75g + prothioconazole 150g
Imtrex	2.0	fluxapyroxad 125g
Kayak	1.5	cyprodinil 450g
Priaxor	1.5	fluxapyroxad 112.5 + pyraclostrobin 225g
Proline275	0.72	prothioconazole 198g
Siltra Xpro	1.0	bixafen 60g + prothioconazole 200g
Talius	0.25	proquinazid 50g
Torch	0.9	spiroxamine 720g
Treoris	2.5	penthiopyrad 250g + chlorothalonil 625g
Vertisan	1.5	penthiopyrad 300g
Zulu	1.0	isopyrazam 125g

Two sites were selected to test net blotch and rhynchosporium control and one site each for ramularia and powdery mildew. The timings of fungicide applications were adjusted according to pathogen development following consultation with the Study Director.

Rhynchosporium trials

SRUC, Lanark (sites 1, 9, 16, 23) and ADAS, Cardigan (3, 11, 18, 25) tested eight different fungicides each year at T1 application (GS31), with four doses (25%, 50%, 100% and 200% of full label rate), to determine the effects of treatment and dose on rhynchosporium control. Treatments at sites 7, 15, 22 and 29 (Teagasc, Carlow) were applied at GS45 to 49 in 2015 and 2016, GS37 to 39 in 2017 and 2018. Treatments that were consistent with those in the UK trials were included in the data.

Powdery mildew trials

Sited at SRUC, Lanark, each year these trials tested eight different fungicides applied at T1, at four doses (25%, 50%, 100% and 200% of full label dose rate), to determine the effects of treatment and dose on control of powdery mildew (sites 2, 10, 17 and 24).

Net blotch trials

Sites at High Mowthorpe (sites 4, 12, 19 and 26) and in Norfolk (sites 5, 13, 20 and 27) tested the effects of eight different fungicide treatments each year, applied at four doses (quarter, half, full and double rates) at GS37 to 39, on net blotch control.

Ramularia trials

Sites 6, 14, 21 and 28 at SRUC, Midlothian applied eight fungicides at four doses (quarter, half, full and double rates) to evaluate their effects on ramularia control. The trials were oversprayed at GS30 with Comet 200 (0.5 l/ha) and treatments were applied at GS37 to 39 in 2015 and 2016; in 2017 and 2018, trials were oversprayed with Bravo (1.0 l/ha) and Comet 200 (1.25 l/ha) before treatments were applied at GS45 to 49 to minimise the risk of early leaf loss to non-target diseases.

3.2.4. Assessments and records

Assessments of leaf disease and green leaf area

Tillers were randomly selected and foliar disease assessments were carried out by estimating the percentage of green leaf area and the area affected by disease (including any necrosis and chlorosis associated with the disease).

Fungicide sensitivity was assessed in the net blotch trials in 2017. A total of 50 to 100 leaves with net blotch symptoms were collected from across the trial area pre-application and subsequent collections were made 3 to 4 weeks after the last foliar spray, collecting 25 of the youngest leaves from each replicate of untreated, Zulu, Vertisan and Imtrex (full dose). This was a contribution to other AHDB work and as such, the results are not reported here.

Disease assessments at all sites took place to calculate mean scores for each foliar disease present (including non-target diseases) and for green leaf area for each individual leaf layer, excluding senesced leaf layers.

Assessment timings were:

1. Immediately before treatments are applied: 40 plants were assessed at random across the trial area and the mean percentage leaf area affected by each foliar disease present was recorded, excluding senesced leaf layers
2. Approximately 3 weeks after treatments were applied, 10 stems per plot were assessed (all treatments, including the untreated)
3. Approximately 6 weeks after treatments were applied, 10 stems per plot were assessed (all treatments, including the untreated)

Assessment timings were more variable for ramularia trials as symptoms most commonly appear after flowering. Two assessments were made at appropriate timings post application.

Assessments of ear diseases

If ear assessments were required, disease was initially assessed on ten ears per plot at GS85 in each untreated plot. All plots were assessed if more than 10% of ear area was affected in untreated plots.

Assessment of stem-base diseases

Stem-base diseases were assessed on 25 stems collected at random from the trial area at GS31 to 32, before the first treatment. The presence or absence of individual diseases and for eyespot, the severity expressed as the number of leaf sheaths penetrated was recorded. Twenty-five stems from crops were assessed again at GS75, with a full disease assessment taking place on all plots if >25% stems were affected by moderate or severe lesions of any disease or if >10% stems with severe lesions of any disease.

Lodging

The percentage plot area lodged was recorded just prior to harvest, if plots were affected by lodging.

Yield

All plots were harvested and grain yield expressed at 85% dry matter.

Grain quality

Specific weight was recorded, expressed at 85% dry matter.

Agronomic records

Details of site, soil type and all agrochemical inputs were recorded.

3.3. Oilseed rape

3.3.1. Site selection and establishment

The experiments ran over four harvest years (2015 to 2018) across the UK to test fungicide performance against three diseases of oilseed rape: sclerotinia stem rot, phoma leaf spot/stem canker and light leaf spot. There were seven sites each year (two sites for phoma leaf spot/stem canker, three sites for light leaf spot and two sites for sclerotinia stem rot), all selected for high risk of naturally occurring infection. Varieties susceptible to the target diseases, but resistant to non-target diseases, were selected where possible. Disease risk in relation to geographical risk was also considered when selecting varieties (Table 5).

Table 5: Site numbers, locations, harvest years, cultivars and target diseases in oilseed rape trials

Site number	Location	Harvest year	Variety	Disease	Treatment application date
1	ADAS, Malton, North Yorkshire	2015	Fencer	Light leaf spot	24th November, 17th February
2	SRUC, Midlothian	2015	PR46W21	Light leaf spot	29th October, 15th March
3	ADAS, Boxworth, Cambridgeshire	2015	Catana	Phoma leaf spot/ stem canker	30th October, 9th December
4	ADAS, Terrington, Norfolk	2015	Catana	Phoma leaf spot/ stem canker	31st October, 9th December
5	ADAS, Rosemaund, Herefordshire	2015	Advance	Sclerotinia	20th April
6	ADAS, Cardigan	2015	PT229CL	Sclerotinia	23rd April
7	NIAB, Dorset	2015	Harper	Light leaf spot	23rd November, 25th February
8	ADAS, Malton, North Yorkshire	2016	PR46W21	Light leaf spot	26th November, 12th February
9	SRUC, Midlothian	2016	Fencer	Light leaf spot	25th November, 26th February

10	ADAS, Boxworth, Cambridgeshire	2016	Catana	Phoma leaf spot/ stem canker	23rd October, 15th December
11	ADAS, Terrington, Norfolk	2016	Catana	Phoma leaf spot/ stem canker	26th October, 7th December
12	ADAS, Rosemaund, Herefordshire	2016	Troy	Sclerotinia	6th May
13	ADAS, Cardigan	2016	Veritas	Sclerotinia	3rd May
14	NIAB, Dorset	2016	Harper	Light leaf spot	18th November, 25th March
15	ADAS, Malton, North Yorkshire	2017	Fencer	Light leaf spot	28th November, 7th March
16	SRUC, Midlothian	2017	Fencer	Light leaf spot	2nd November, 10th March
17	ADAS, Rosemaund, Herefordshire	2017	Incentive	Phoma leaf spot/ stem canker	27th October, 14th February
18	ADAS, Terrington, Norfolk	2017	Catana	Phoma leaf spot/ stem canker	15th November, 5th January
19	ADAS, Rosemaund, Herefordshire	2017	Troy	Sclerotinia	14th April
20	ADAS, Cardigan	2017	Veritas	Sclerotinia	13th April
21	NIAB, Dorset	2017	V316 OL	Light leaf spot	11th November, 10th March
22	ADAS, Malton, North Yorkshire	2018	Fencer	Light leaf spot	14th November, 26th March
23	SRUC, Midlothian	2018	Fencer	Light leaf spot	2nd November, 10th March
24	ADAS, Rosemaund, Herefordshire	2018	Catana	Phoma leaf spot/ stem canker	23rd October, 20th December
25	ADAS, Terrington, Norfolk	2018	Catana	Phoma leaf spot/ stem canker	9th October, 21st November
26	ADAS, Rosemaund, Herefordshire	2018	Elgar	Sclerotinia	26th April
27	ADAS, Cardigan	2018	Veritas	Sclerotinia	29th April
28	NIAB, Dorset	2018	Campus	Light leaf spot	3rd November, 6th March

At each site, the trials were drilled at the correct seed rate for the locality to achieve 50 plants/m^2 or an equivalent commercial crop was used. The size of the plots in each trial was a minimum of 40 m^2.

Soil samples from each site were analysed for pH, nutrient content and % organic matter. Good farm practice was followed for all inputs to ensure that the trials were not affected by nutrient deficiencies or pest and weed infestations. Fungicides were applied, where appropriate, to control non-target diseases to minimise their impact on yield.

3.3.2. Experiment design

A randomised block design incorporating standard randomisation of treatments within each replication was used, with 30 treatments including two untreated controls, replicated three times. The untreated control plots were randomised within the trial, with one in each half of the block. Fungicides were applied at 25%, 50%, 75% and 100% of recommended label rates.

3.3.3. Fungicide treatments

Fungicides were applied in 200 litres water/ha using pressurised hand-held plot spraying equipment, to produce a medium quality spray.

Phoma leaf spot/stem canker treatments were applied as two spray programmes, with the first application at early disease onset (10 to 20% plants affected) and the second timing about six to eight weeks later, when re-infection was seen in treated plots.

Light leaf spot treatments were applied as two spray programmes; the first application was applied at or before the first appearance of visible symptoms in October/early November followed by the second application when symptoms are found in treated plots, typically from February onwards. In 2017 and 2018, to investigate whether treatment timing had an effect on disease control, an overspray of 0.5 l/ha of Skyway285 Xpro was applied in November and fungicide treatments were only applied in the spring, either at GS30 (rosette stage: beginning of stem extension, reached in early March) or when symptoms were first seen. This switch to a single timing for the test fungicide was made to accommodate the testing of fungicides where only one application was approved.

Treatments were applied as a single application in sclerotinia stem rot trials, at early to mid-flowering (GS4,3 to 4,5) and ideally before significant petal fall in the crop.

Fungicides tested included a range of existing products that were commercially available and those in the process of registration. Data for the latter have been released as products have become commercially available. Several products have been registered or withdrawn during the course of the project. The results are included here for completeness, however, it should be noted that any withdrawn products can no longer be used. Fungicide doses stated in this report are all expressed as a percentage of full label rates. Full label rates for each product tested are given in Table 6.

Table 6: Full label rates (l/ha), and active substance (g/ha), for products tested for the control of one or more diseases of oilseed rape between 2015 and 2018.

Product tested	Full label rate l/ha	Active substance (a.s.) g/ha at full label rate
Amistar	1.0	azoxystrobin 250g
Cirkon	1.125	prochloraz 450g + propiconazole 101.25g
Filan	0.5 kg/ha	boscalid 500g
Orius P	1.5	tebuconazole 199.5g + prochloraz 400.5g
Orius20EW	1.25	tebuconazole 250g
Pictor	0.5	boscalid 100g + dimoxystrobin 100g
Plover	0.5	difenoconazole 125g
Proline	0.63	prothioconazole 173.25g
Refinzar*	1.0	penthiopyrad 160g + picoxystrobin 80g

*withdrawn from use 30 November 2018

3.3.4. Assessments and records

Background assessments for all foliar, stem and pod diseases

Background disease assessments evaluated the incidence (percentage of plants affected) and severity (percentage leaf, stem or pod area affected by the specific disease) as appropriate. All diseases, including phoma leaf spot/stem canker (A and B), light leaf spot, alternaria, botrytis and powdery mildew were recorded.

Background disease assessments were carried out at phoma leaf spot/stem canker trial sites by selecting 25 plants from across the untreated plots each month from late September to confirm the first application date. A similar strategy was used to determine when re-infection occurred to identify the timing for the second application. To determine disease levels at the first and second fungicide application, 10 plants per untreated plot were assessed for all diseases as described previously.

In 2015 and 2016, light leaf spot trial sites were assessed monthly from late September/October until the pre-harvest assessment, by selecting 25 plants from across the untreated discard plots to monitor disease development. In 2017, background assessments on 25 plants were completed weekly from late October until T1 then monthly until harvest. In 2018, the assessment frequency was increased to fortnightly assessments between T1 and T2 applications. For all these assessments, plants were destructively sampled and incubated for 48 hours prior to assessing for disease as described previously.

For sclerotinia stem rot trials, background disease assessments were carried out by selecting a minimum of 25 plants across the untreated plots at fungicide application, the end of flowering and pre-harvest. These assessments were carried *in situ* on untreated plots.

Main disease assessments

Phoma leaf spot/stem canker disease assessments were carried out by selecting 10 plants per plot at T2 application, 6 to 8 weeks after T2 application and as required after this time. Twenty-five plants per plot were assessed for incidence and severity of all stem disease pre-harvest.

In the light leaf spot trials, 10 plants per plot were assessed for incidence and severity of all diseases present at the first and second fungicide application and at 6 to 8 weeks after T2 application. In 2017 and 2018, there was another non-destructive assessment at 8 to 11 weeks after second application. A final assessment of 25 plants from each plot was carried out *in situ* for incidence and severity of all stem diseases. All plants that were destructively sampled were incubated for 48 hours prior to assessing disease levels.

Main disease assessments were carried out in the sclerotinia trials after flowering and shortly before harvest. The incidence and severity of sclerotinia stem infection was recorded on minimum of 100 plants per plot using 4 x 25 plants in rows, avoiding plot edges. The incidence and severity (0 to 4 index) was recorded separately for main stem and lateral stem infections, distinguishing stem base lesions from those higher up the main stem. This assessment method provides more detailed separation of severe lesions and dead plants. If other diseases were apparent at significant levels, these were also recorded.

Petal tests were carried out at time of the spray application, mid to late flowering (at least 7 days after spray application) and at the end of flowering; 10 main racemes were selected from across at least three control plots representative of the whole trial area. Four petals, representing a range of ages from each raceme, were equally spaced on 9 cm petri dishes containing potato dextrose agar containing streptomycin (PDA + strep). After incubation at 20˚C, the incidence of *S. sclerotinium, Botrytis spp.* and other fungi on each petal was recorded 5 to 7 days and 10 to14 days after plates were set up.

Phytotoxicity, including yellowing, discolouration and stunting was assessed at all disease assessments, 14 days after fungicide treatment and at harvest. Percent phytotoxicity was recorded for each plot.

Lodging

Lodging was assessed upon occurrence and prior to harvest. The percentage area of each plot affected was estimated with the severity of lodging recorded on a 0 to 100 scale where 0 = stem vertical and 100 = stem horizontal.

Yield

Yield was assessed and adjusted to 91% dry matter.

Grain quality

Seed moisture was recorded for all plots.

3.4. Data handling

Disease, green leaf area, yield and grain quality data were collected manually or directly onto portable computers. All data were transferred to Microsoft Excel worksheets after collection.

3.5. Statistical analysis

3.5.1. Individual season and site assessments

In all crops, disease and yield was summarised for all sites/seasons by analysis of variance and the validity of the analysis was checked by examination of the residuals. Exponential dose-response curves were plotted for each fungicide/activity using the equation $y = a + be^{kx}$ (y = % disease or yield and x = proportion of the full label application rate). All curves were constrained to pass through the mean of the untreated plots.

For septoria tritici and rhynchosporium, treatment means were calculated separately for protectant and curative activities. At each site, fungicide activity (protectant, curative, mixed) was categorised based on emergence of each leaf layer relative to spray timing. Treatments were deemed to have protectant activity on leaves just emerged or still to emerge at the time of treatment or curative activity on the first two non-protectant leaves down the stem. Bravo (chlorothalonil), a fungicide known only to have protectant effect was used as a check for septoria tritici. For all other diseases, the curative and protectant categories were not distinguished.

Variables were assessed on a site-by-site basis, by assessment date and leaf layer and those that did not contribute useful or reliable information were excluded from analysis. This included data where there was no significant effect of treatment and where disease averaged less than 3% or more than 70% on the untreated plots. Assessments where more than one disease was recorded on a particular date were examined to determine if results for either disease were compromised by an interaction; any compromised assessments were excluded from analysis.

3.5.2. Combining results from different sites and seasons

Each season, results from all sites were combined to provide an across site mean for disease and yield. Analysis from previous fungicide performance projects has shown that, whilst no transformation is needed for yield, a logit transformation of % disease provides a more valid analysis and can be back-transformed for ease of evaluation. This process provided a more equal weighting between sites.

Residual maximum likelihood (REML) has been developed for the analysis of across site and across year data analysis. The REML method has the advantage of including information on product differences that may be available in site means and of calculating the appropriate weight to give this information in the combined means. REML means are always between the individual site means and the combined means. If the variability between sites was small relative to the variation within sites, REML means would be close to the unadjusted means.

REML analysis is sensitive to the proportion of the data matrix that is missing. Although it is theoretically possible to include all the data from individual assessment dates and leaf layers at each site, the resulting matrix is sparse and investigation has shown that the method does not converge to give a solution. Therefore the average percentage disease was calculated from the leaves categorised as showing curative, protectant or mixed activity at each site. This provided a suitable measure of disease for combining over experiments using the REML method. Exponential curves were fitted to the REML adjusted means to provide over-site means and season summaries.

4. Results

4.1. Wheat

4.1.1. Septoria tritici

Disease control

In 2015, differences in protectant efficacy could be seen between the different fungicide modes of action tested. The triazoles, Proline (prothioconazole) and Ignite (epoxiconazole), showed less activity than the SDHIs, Imtrex (fluxapyroxad) and Vertisan (penthiopyrad), and the SDHI-azole mixtures, which performed similarly to each other at all doses. The mixtures included Adexar (epoxiconazole + fluxapyroxad), Aviator Xpro (prothioconazole + bixafen), Ascra Xpro (bixafen, prothioconazole + fluopyram), Librax (fluxapyroxad + metconazole) and Vertisan + Ignite (Figure 1). A half dose of Bravo (chlorothalonil) (1.0l/ha) provided a similar level of protection to a half dose of any of the straight SDHI or the mixture treatments.

The 2015 season proved to be a tough test of curative activity where it was observed. Proline showed little or no curative activity at any dose, whilst the SDHIs exhibited similar levels of activity to the SDHI-azole mixtures (Figure 5). Of the SDHI azole mixtures, Aviator appeared slightly less effective than Adexar, Ascra Xpro and Vertisan + Ignite. Librax appeared to be the most curative treatment.

In 2016, the straight SDHIs (Imtrex and Vertisan) showed more effective curative (Figure 6) and protectant activity (Figure 2) than the triazoles and displayed similar levels of activity to the SDHI-azole mixtures Ascra Xpro, Aviator Xpro, Elatus Era (benzovindiflupyr + prothioconazole), Librax and Vertisan + Ignite. Proline showed greater activity than Ignite, although both these treatments showed less protectant activity than Bravo, which was similarly effective to the treatments containing SDHIs.

In 2017, a similar pattern of activity was observed in protectant (Figure 3) and curative (Figure 7) situations. The triazole standards, Proline and Ignite, provided similar levels of control to each other but were outperformed by the solo SDHIs, Imtrex and Vertisan, at both 50 and 100% doses. Elatus Era and Ascra Xpro provided similar levels of curative activity but a slightly improved protectant activity compared to the solo SDHIs, indicating that the azole component was adding to the SDHI activity. Librax showed a higher level of curative activity compared to Elatus Era and Ascra Xpro but showed similar protectant activity. At 50% doses, Imtrex and Vertisan gave protectant activity equal to the Bravo standard, whilst all the SDHI-azole mixtures reduced disease levels more than Bravo.

Across the protectant trials in 2018, the SDHI-azole treatments were more effective than either the azoles, SDHIs or chlorothalonil applied alone (Figure 4). Of the three SDHI-azoles, Ascra Xpro appeared the most effective, though differences were small. Ignite and Proline showed the least activity with Proline appearing to be more effective than Ignite. More variation could be seen in the curative data (Figure 8), due to low disease pressure and data from a limited number of sites. Despite this, Librax again appeared to be the most effective curative treatment. Similarly, the straight triazoles were the least effective at 100% doses.

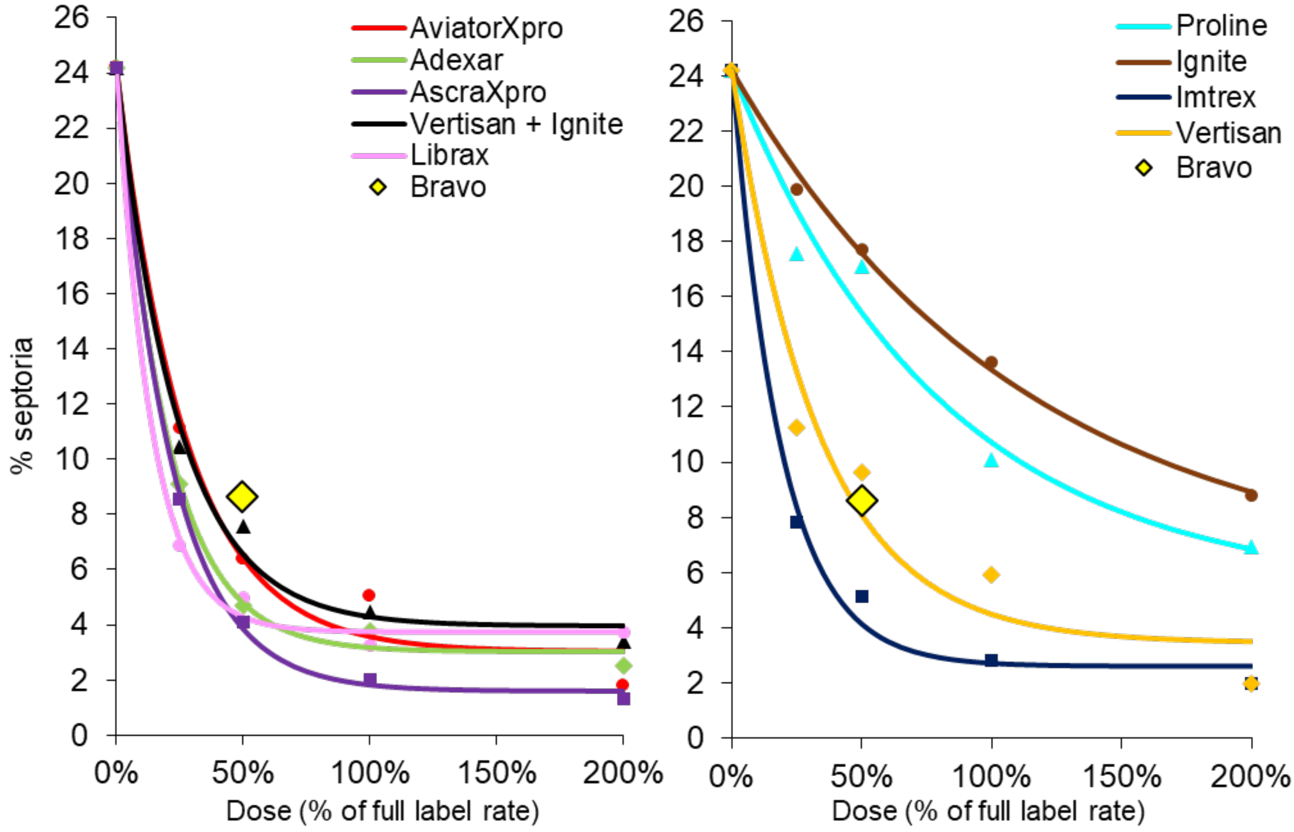

Figure 1: Fungicide dose-response curves for protectant activity against septoria tritici in 2015 (mean of six trials)

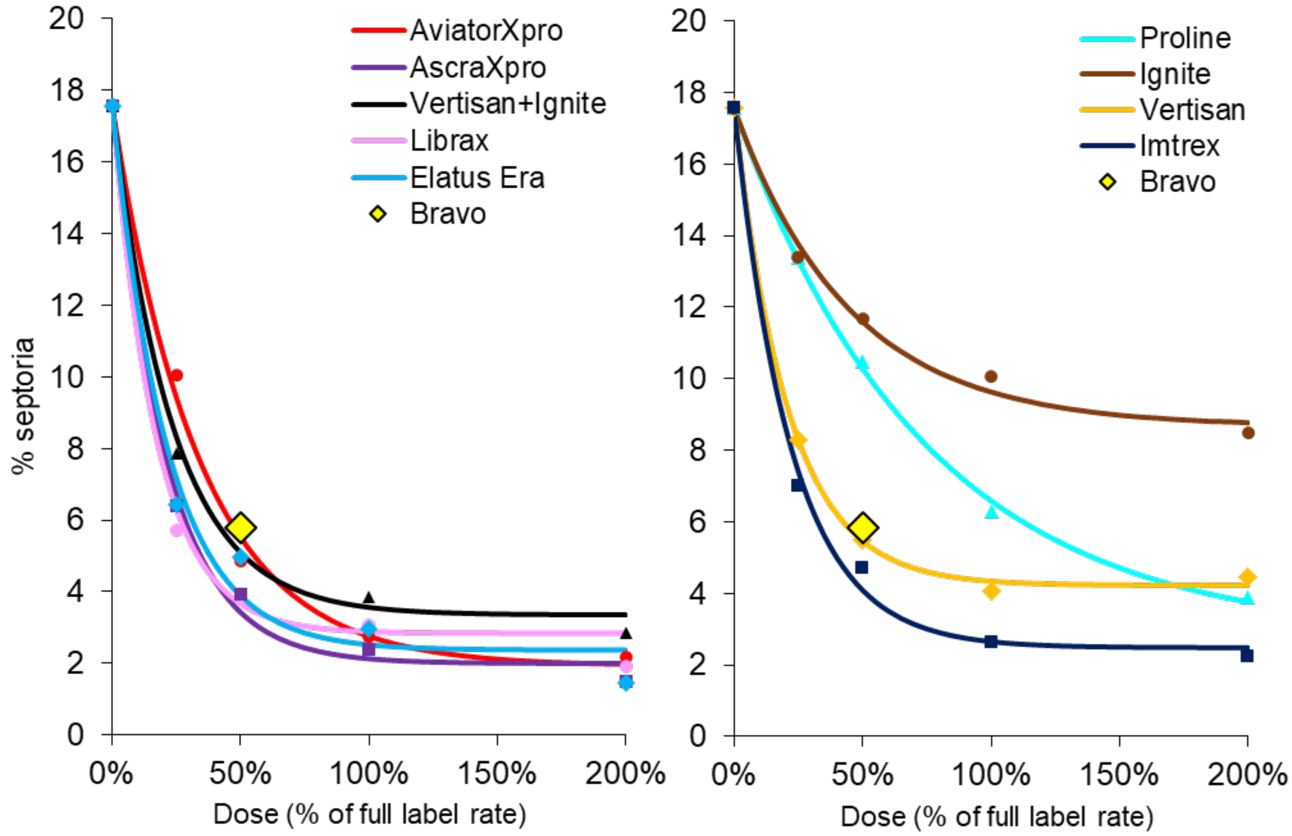

Figure 2: Fungicide dose-response curves for protectant activity against septoria tritici in 2016 (mean of seven trials)

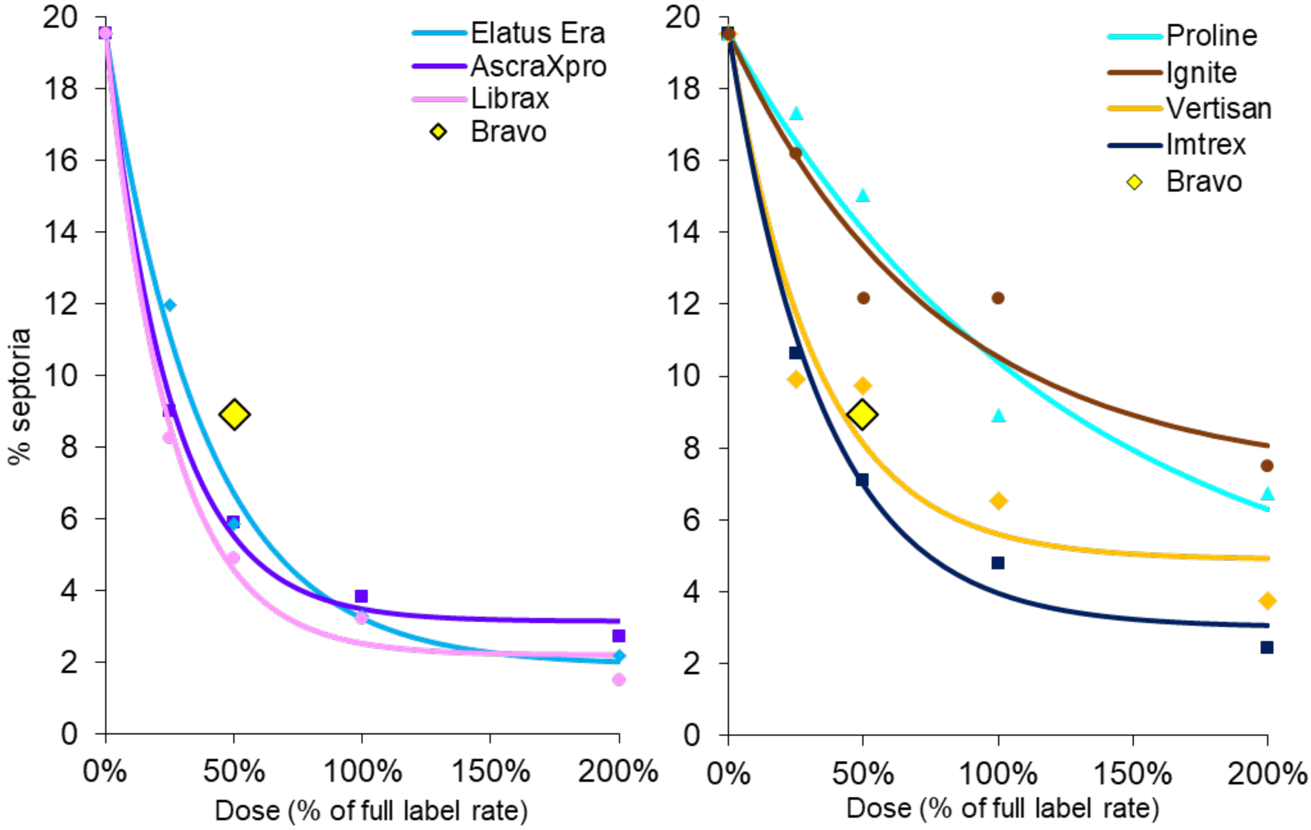

Figure 3: Fungicide dose-response curves for protectant activity against septoria tritici in 2017 (mean of six trials)

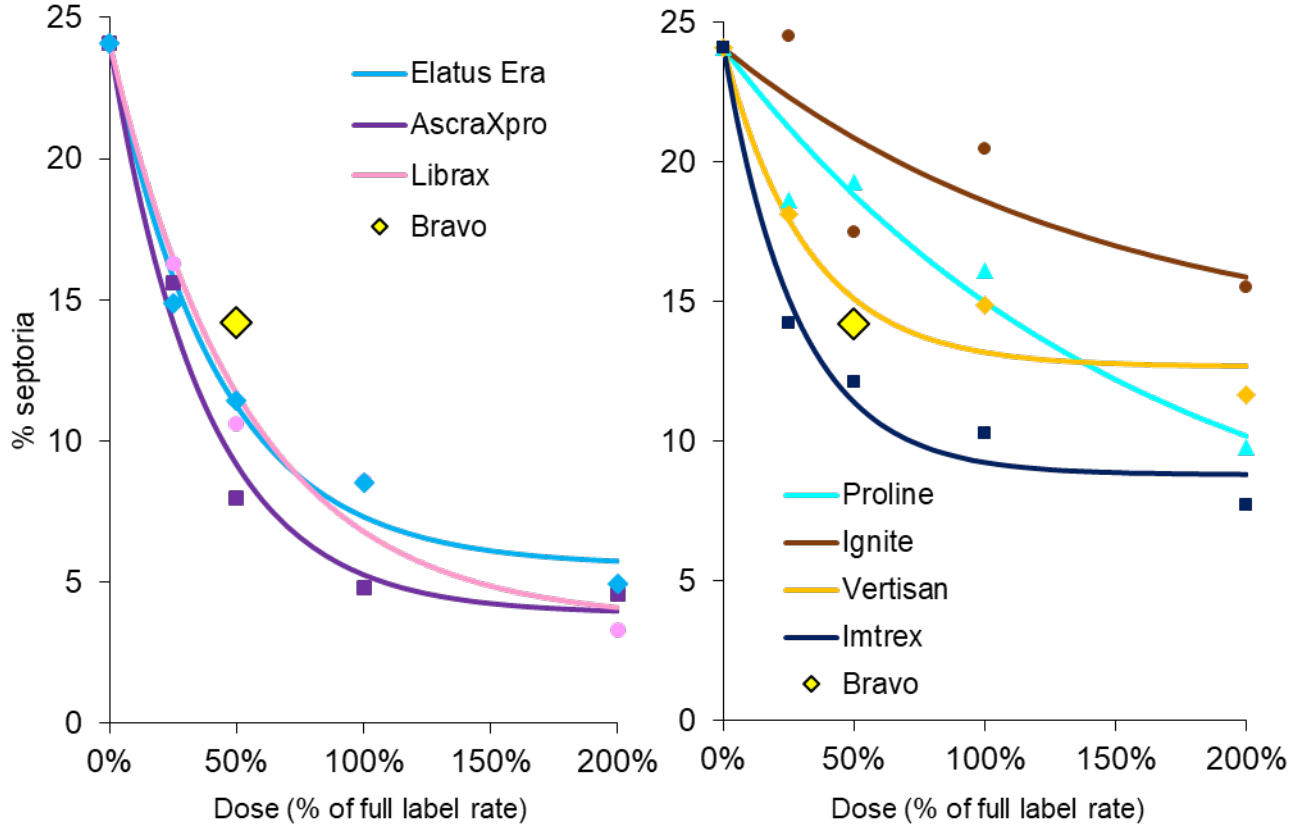

Figure 4: Fungicide dose-response curves for protectant activity against septoria tritici in 2018 (mean of four trials)

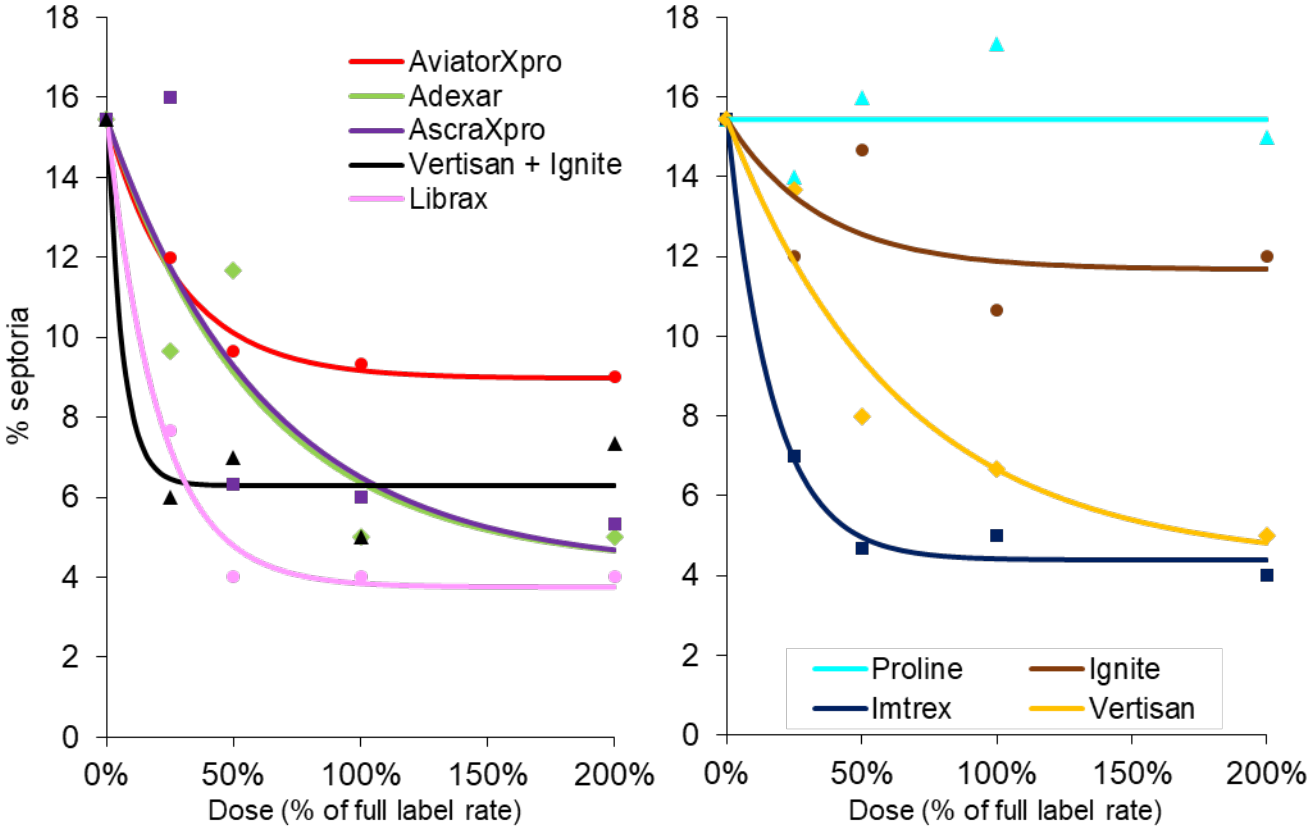

Figure 5: Fungicide dose-response curves for curative activity against septoria tritici in 2015 (one trial)

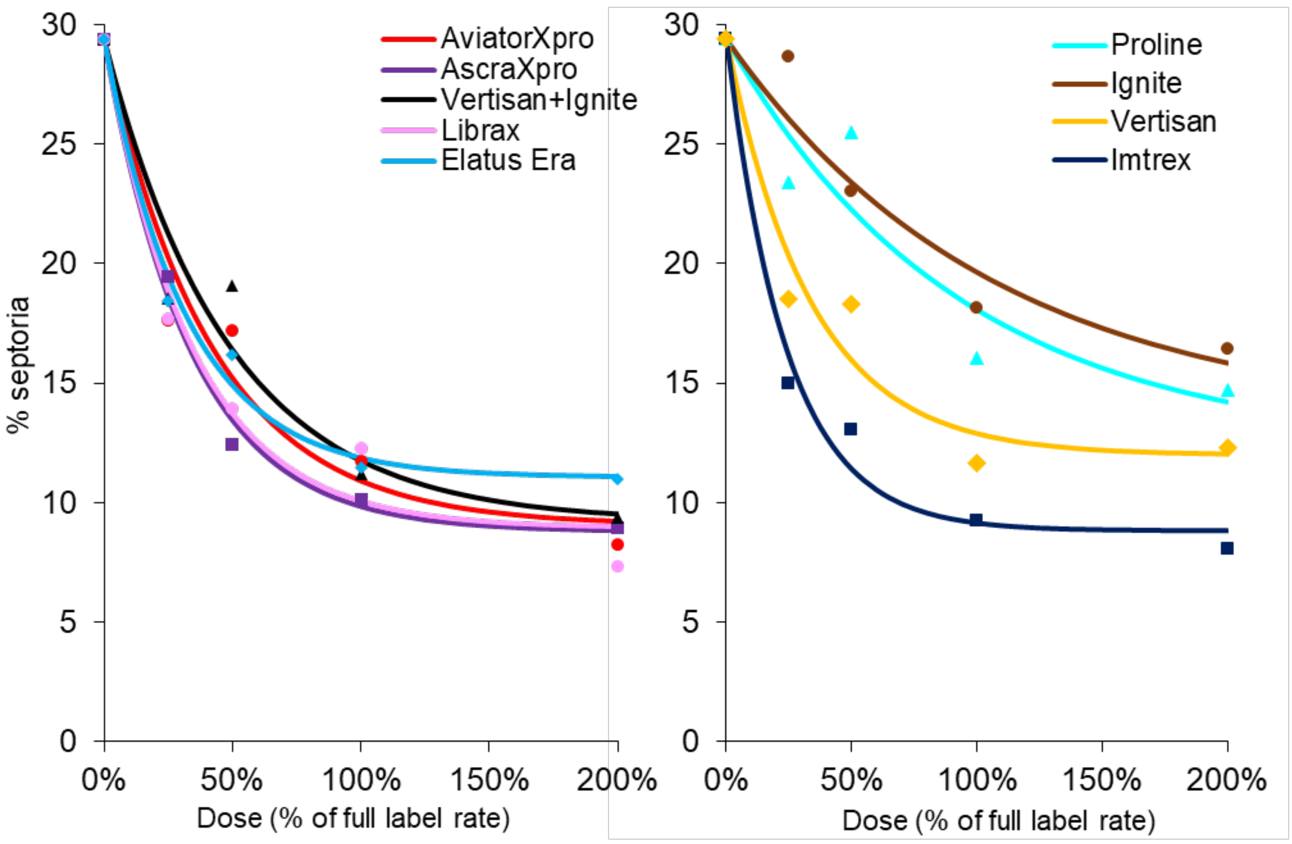

Figure 6: Fungicide dose-response curves for curative activity against septoria tritici in 2016 (mean of four trials)

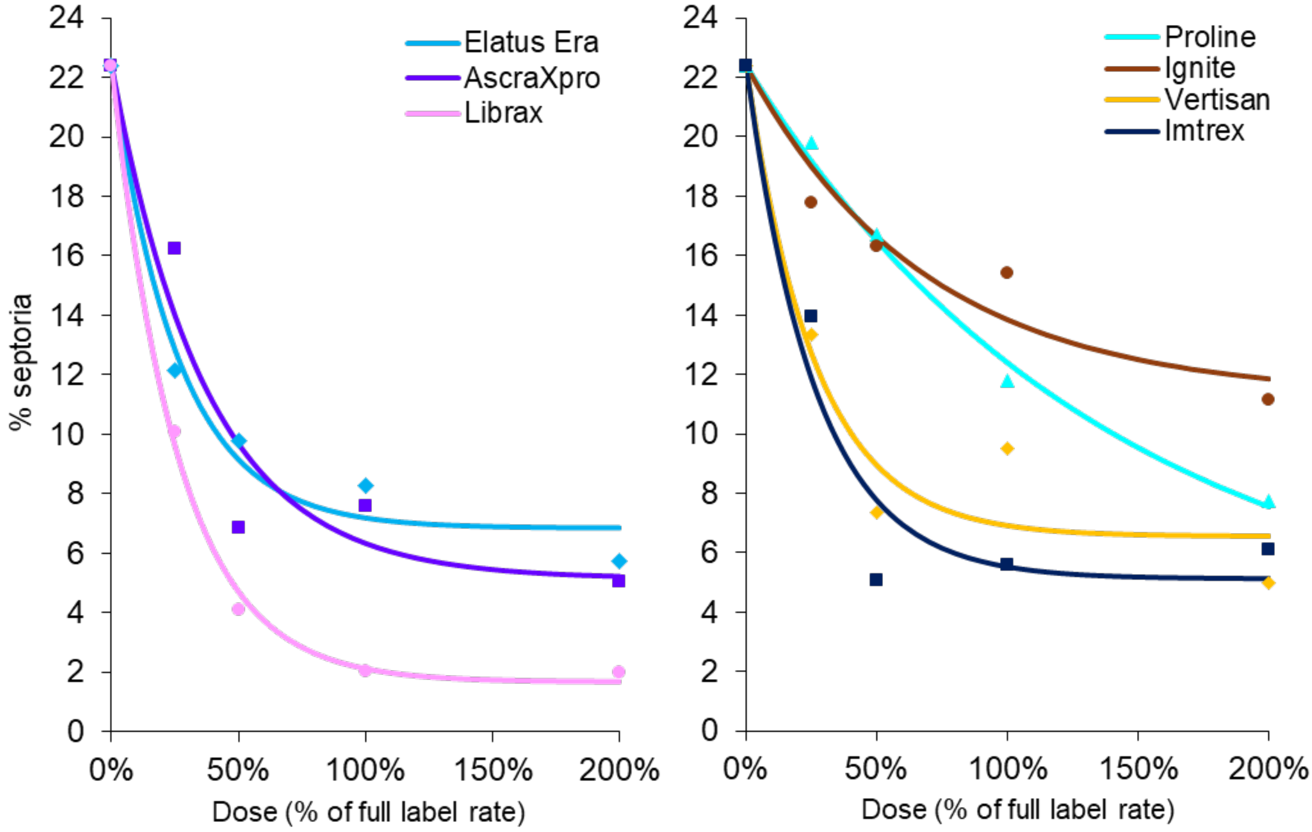

Figure 7: Fungicide dose-response curves for curative activity against septoria tritici in 2017 (mean of three trials)

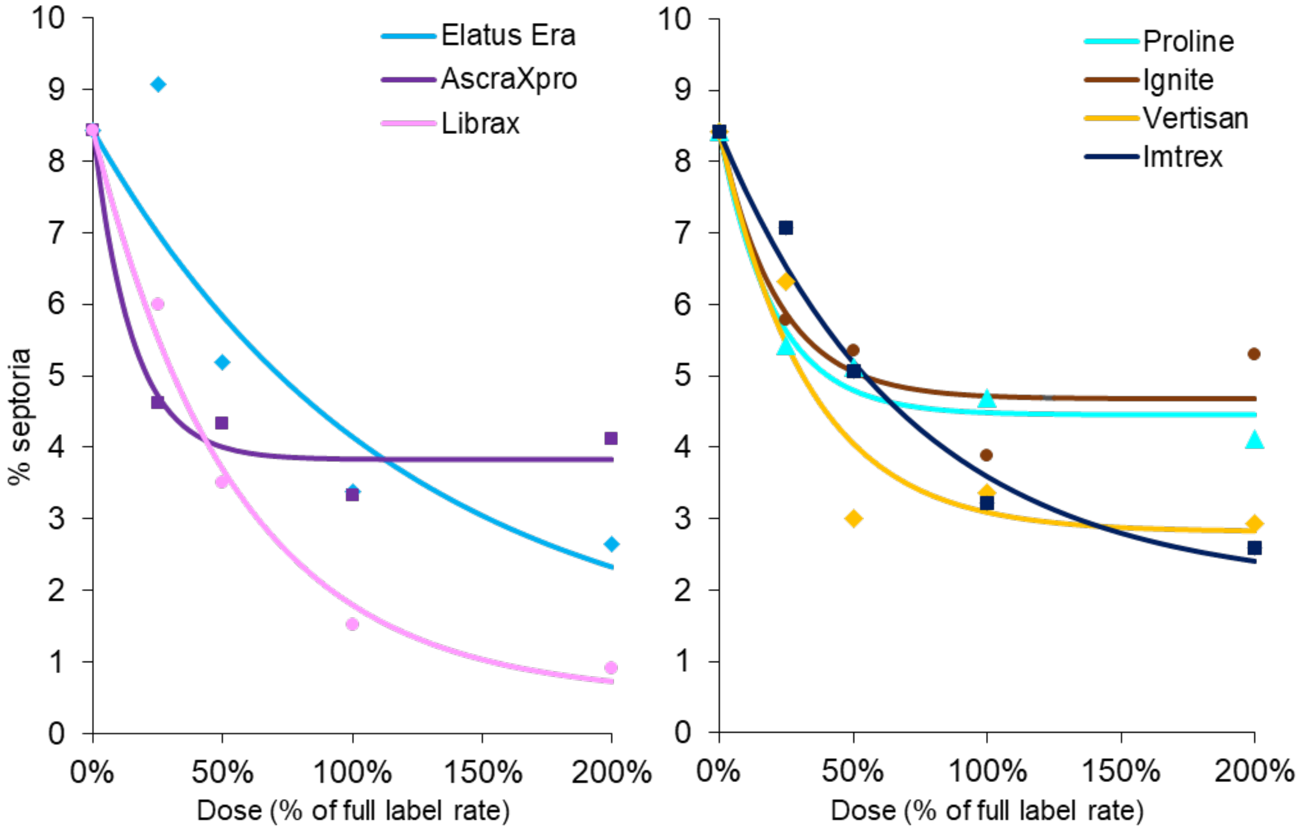

Figure 8: Fungicide dose-response curves for curative activity against septoria tritici in 2018 (mean of three trials)

Yield

In practice, commercial wheat disease control strategies involve between two and four fungicide application timings, with products often being applied in mixtures. Yield responses to single spray applications, which do not fully control disease, will not reflect yield responses that will be seen in practice where a more comprehensive strategy is employed. These results however, are of use to compare the relative activity of different active substances and any shifts in efficacy over time. They can also indicate differences in the duration of control achieved from different products. Products with greater persistency may show a similar level of disease control at point of assessment, but can out yield other treatments by continuing to protect beyond the assessment period.

Wheat yields in 2015 were high, with the untreated trial plots averaging 9.18 t/ha (Figure 9). The triazoles, Proline and Ignite, produced the lowest average yield responses at full dose rates (0.74 t/ha and 0.32 t/ha), whilst the straight SDHIs (Imtrex and Vertisan) produced responses similar to those produced by the SDHI-azole mixtures. Bravo at 50% of full label rate (1.0 l/ha) produced yield responses that were below those seen for mixture treatments and the straight SDHIs, but comparable to the responses produced by triazole treatments at full label rate. The SDHI–azole mixtures all showed similar yield responses, with the exception of Ascra Xpro, which produced the highest yield at both half and full doses. This reflected the observed efficacy of these treatments in protectant situations on septoria tritici (Figure 1).

Yield responses were generally lower in 2016, although a wide range was observed, varying from 0.58 t/ha to 1.76 t/ha (Figure 10). Consistent with the lower level of disease control observed by the triazoles, these treatments showed the lowest yield responses of 0.73 t/ha (Proline) and 0.58 t/ha (Ignite) at full dose rates. The yield response due to Vertisan (1.19 t/ha) was similar to the response achieved by the Vertisan + Ignite mixture, suggesting that the addition of Ignite had little effect. At full application rates, Imtrex yielded similarly to Aviator Xpro and Elatus Era, but these treatments were out yielded by Ascra Xpro and Librax, despite showing similar levels of disease control. Bravo produced a yield response of 0.76 t/ha, which was below that seen for mixed treatments and the SDHIs, but above the responses produced by triazole treatments at a 50% rate.

In 2017, yield increases from applying single full dose applications ranged from 0.53 to 1.30 t/ha (Figure 11). Both triazoles tested gave similar yield responses (0.53 and 0.65 t/ha) at full dose, as did Imtrex and Vertisan, which gave slightly higher yield responses of 0.91 t/ha and 0.94 t/ha respectively. The SDHI-azole mixtures, Ascra Xpro, Elatus Era and Librax showed yield responses of between 1.09 and 1.28 t/ha at full dose. At half dose rates, yields from Bravo treated plots were equivalent to the straight SDHIs and higher than the triazoles.

Yield responses in 2018 ranged from 0.15 t/ha (Ignite) to 1.06 t/ha (Ascra Xpro) at full dose rates (Figure 12). As seen in other years, the azoles applied alone yielded less than the Bravo standard at 50% dose rates. The SDHIs applied alone gave slightly lower yields than Bravo (unlike previous years) whilst the SDHI-azole mixtures (Ascra Xpro, Elatus Era and Librax) showed yield responses equal to, or better than Bravo. Although in 2015 to 2017 the straight triazoles (Proline and Ignite) gave lower yields than the straight SDHIs (Imtrex and Vertisan), in 2018, differences between these two modes of action were less, and Proline (which out yielded Ignite) yielded similarly to Imtrex.

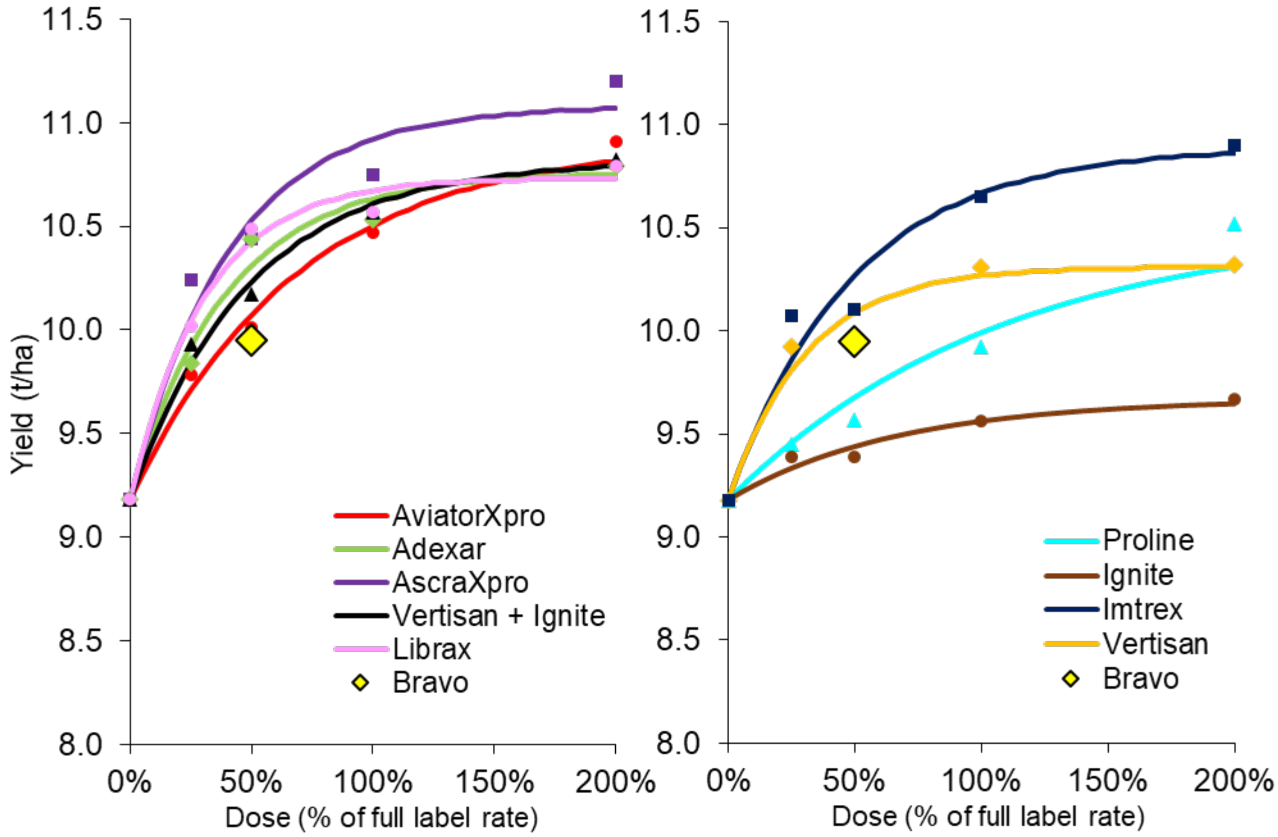

Figure 9: Fungicide dose-response curves for yield against septoria tritici in 2015 (mean of six trials)

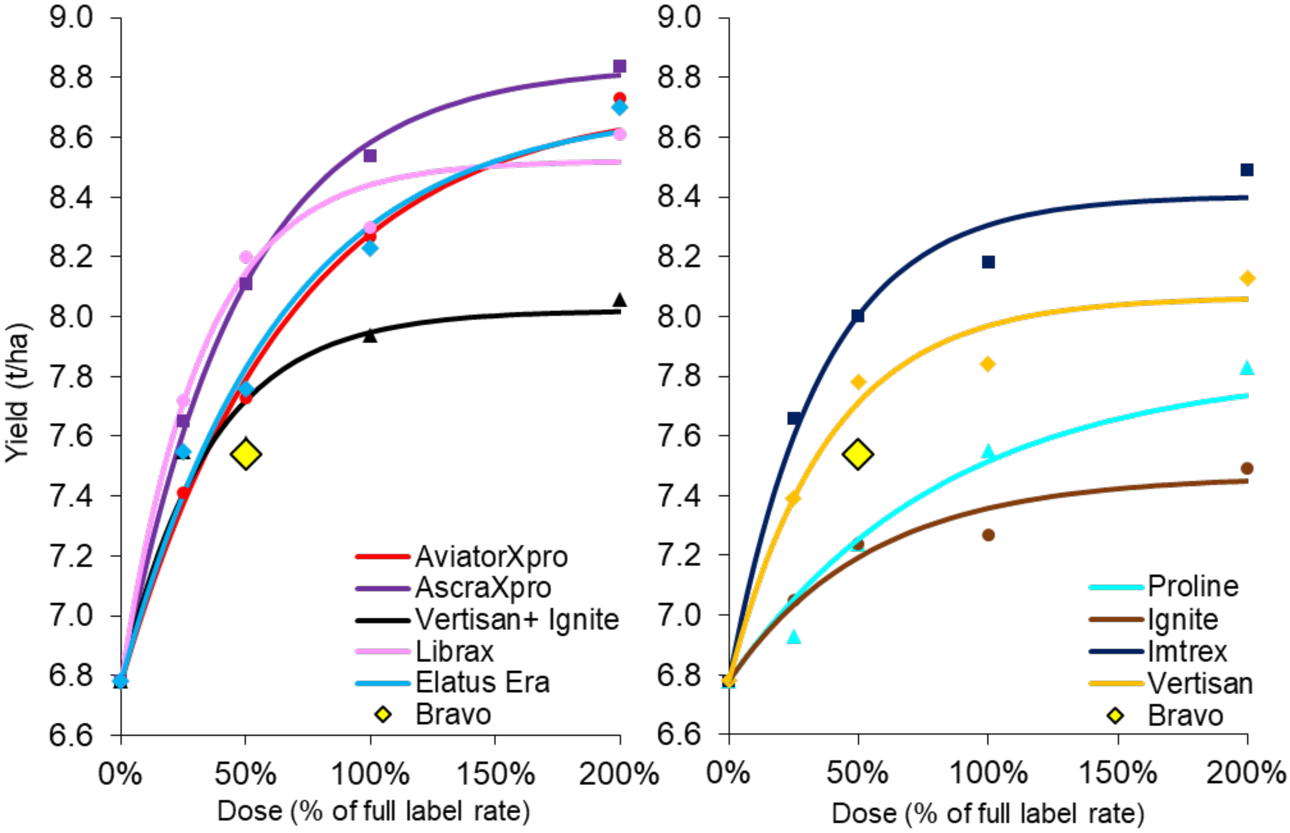

Figure 10: Fungicide dose-response curves for yield against septoria tritici in 2016 (mean of seven trials)

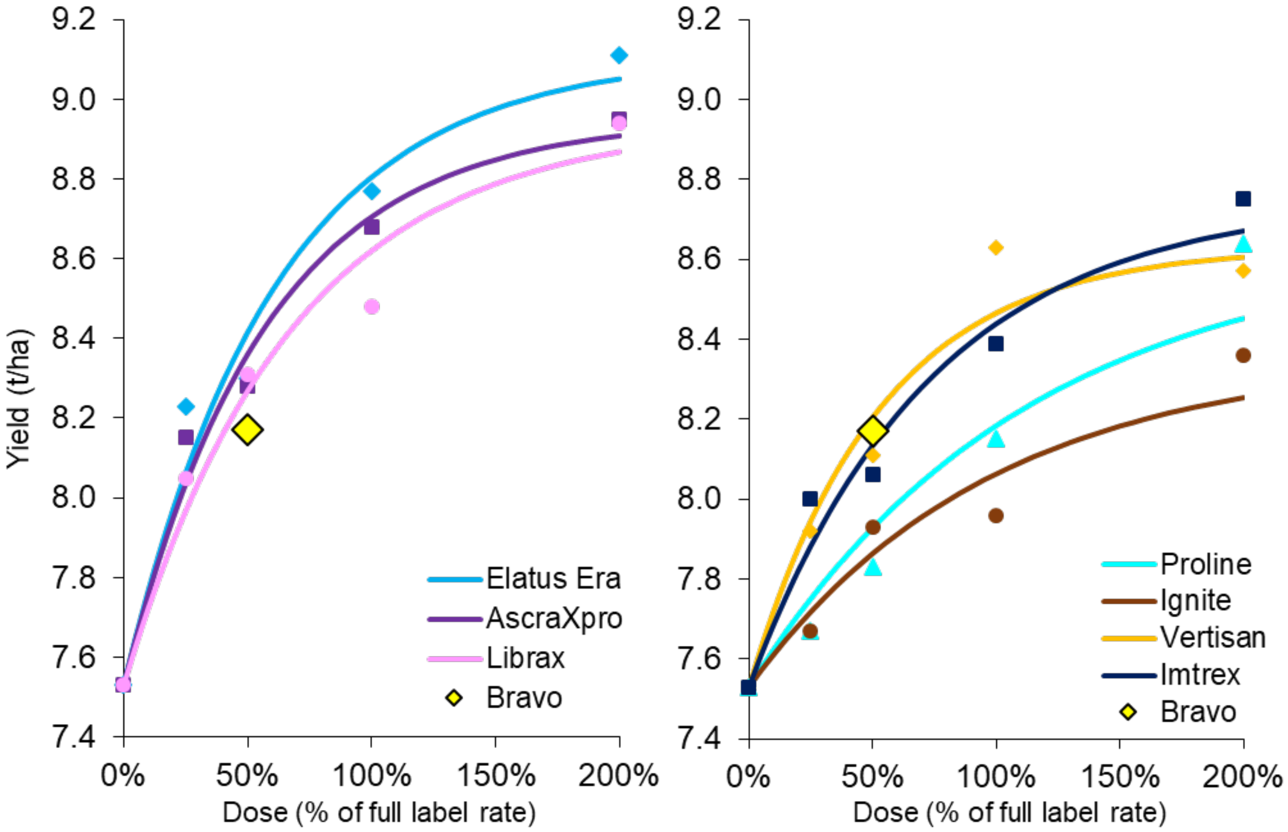

Figure 11: Fungicide dose-response curves for yield against septoria tritici in 2017 (mean of seven trials)

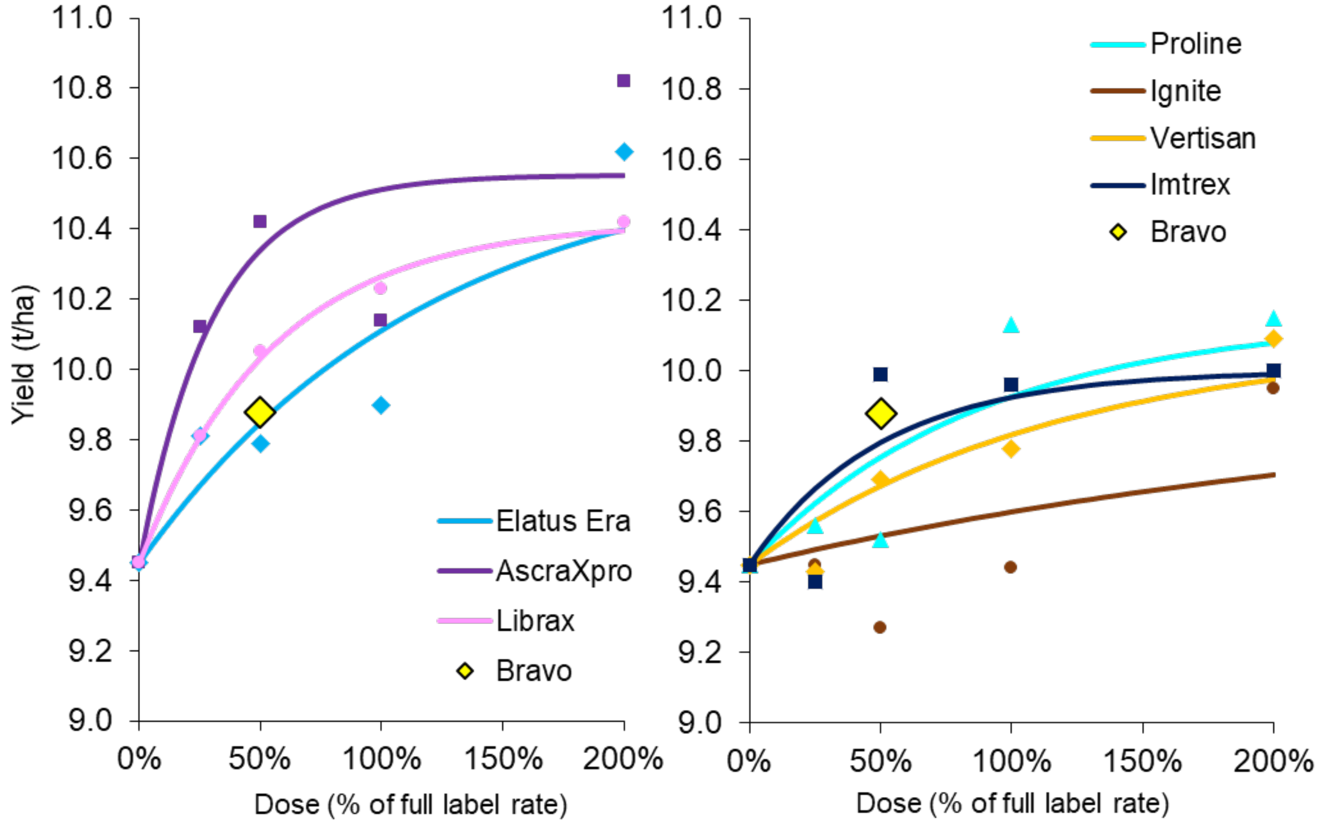

Figure 12: Fungicide dose-response curves for yield against septoria tritici in 2018 (mean of seven trials)

Monitoring of fungicide activity

Activity of the azole-based treatments, Proline and Ignite, has been assessed since the early 2000s, comparing fungicide efficacy to the untreated controls. Between 2015 and 2017, the efficacy achieved by epoxiconazole and prothioconazole appeared similar and quite stable, however a further decline in field efficacy for both these azoles was observed in 2018 (Figure 13).

Protectant activity of SDHI treatments was monitored across the period of this project and for two years previously, with disease control calculated in relation to the untreated. The graphs in Figure *14* indicate a decline in protectant activity provided by full dose rates from 2013 to 2018, with the average control achieved decreasing from between 90% and 100% to 62% for Imtrex and 45% for Vertisan. Additionally, the curve gradient appears to reduce, implying that the efficacy of a half rate application is declining to a greater extent.

Figure 15 shows a similar trend for the SDHI-azole treatments, Ascra Xpro, Elatus Era and Librax, although the addition of a mixture partner to either component appears to be slowing the rate of decline.

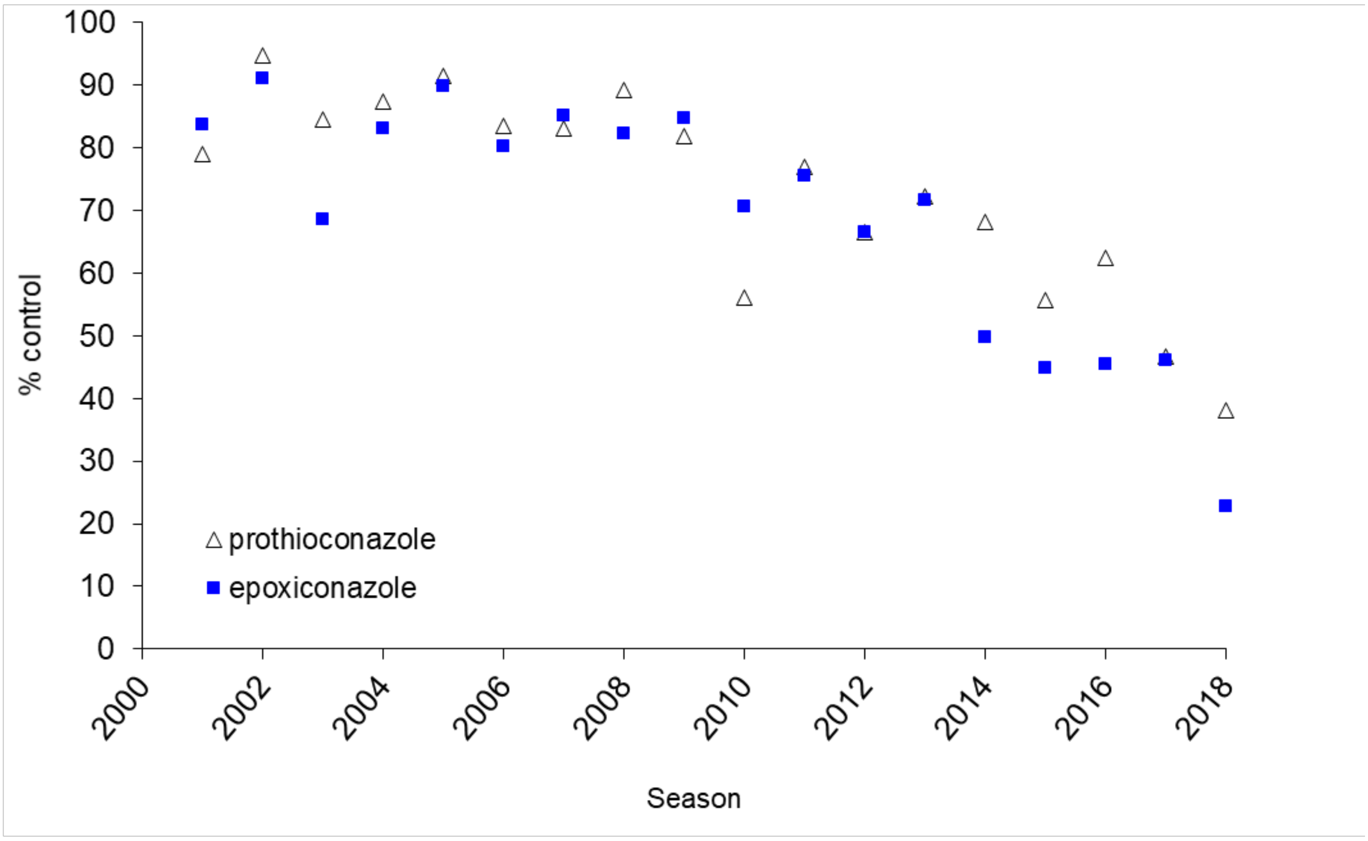

Figure 13: % septoria control of triazoles between 2001 and 2018 for prothioconazole (Proline) and epoxiconazole (Ignite), in protectant situations where full label rate was applied.

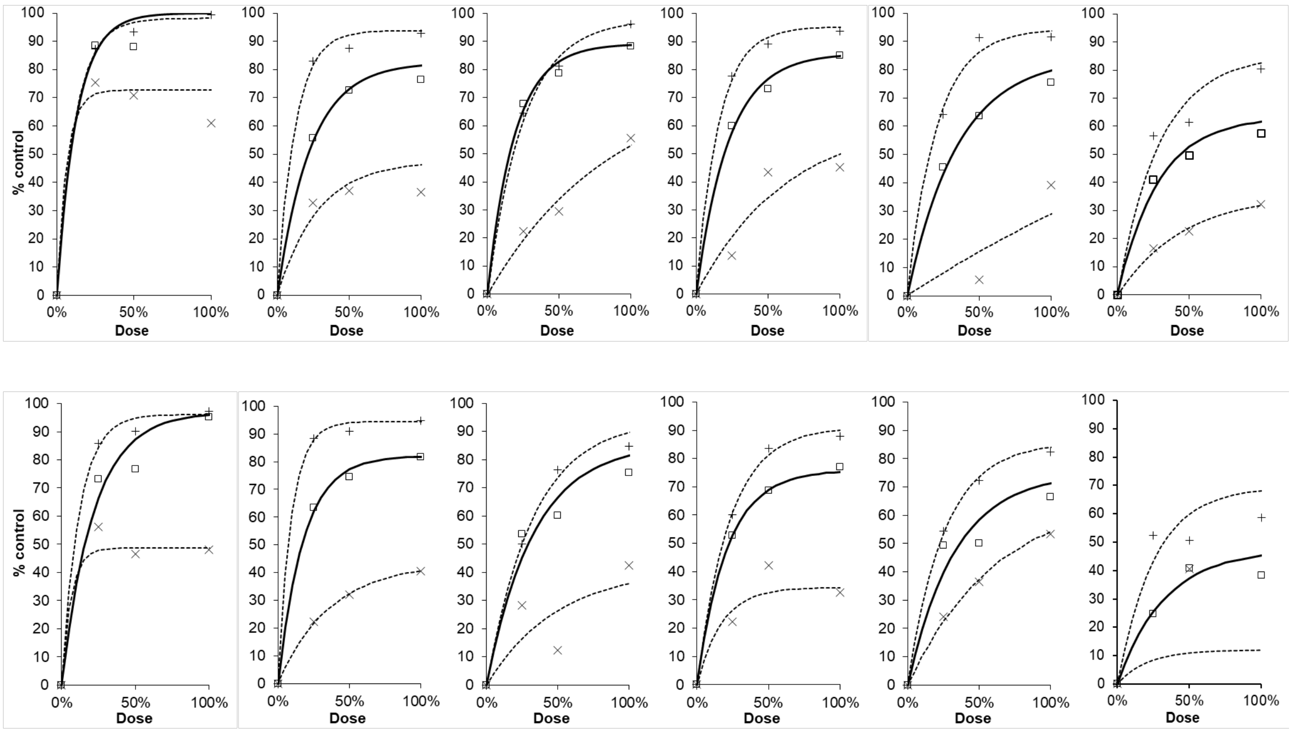

Figure 14: Percent disease control provided by Imtrex (top) and Vertisan (bottom) from 2013 (L) – 2018 (R). Dose is expressed as a percentage of the full label rate. Maximum and minimum control are shown as dashed lines, with the overtrial average shown as a solid line.

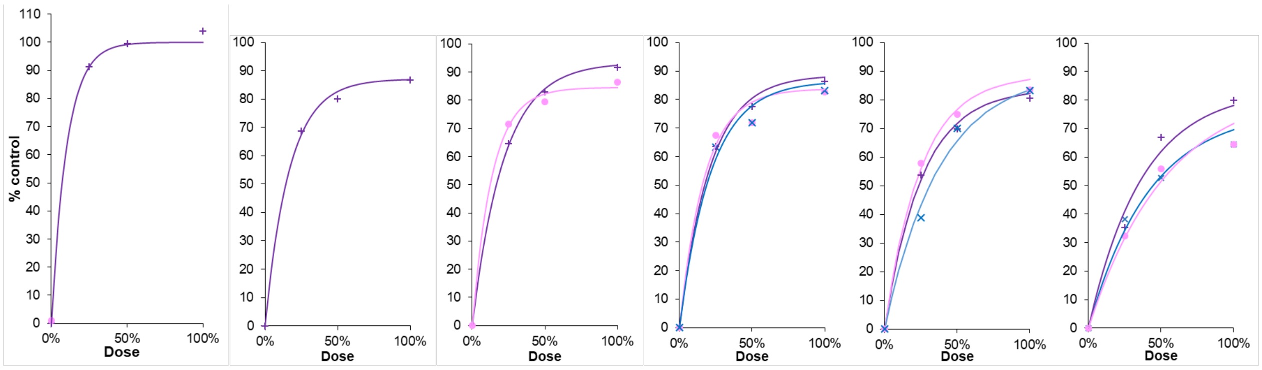

Figure 15: Decline in percent septoria control provided by mixed SDHI-azole treatments from 2013 to 2018. Ascra Xpro is displayed in purple, Elatus Era in blue and Librax in pink. Dose is expressed as a percentage of the full label rate.

Summary

A clear trend in declining activity can be seen across the period of 2013 – 2018 for the straight triazoles, SDHIs and the mixed SDHI-azole treatments. At the start of this project in 2015, the SDHIs were providing around 70 to 80% control of septoria where applied alone and at this time the improvement in efficacy from adding an azole to a SDHI was often small. By 2018, efficacy of SDHIs applied at full label rate in protectant situations had declined to between 40 and 60%, and the addition of azole fungicides as mixture partners were adding a clear benefit in terms of disease control and yield. This is despite the azoles themselves appearing to decline in performance themselves during this period. At a 50% dose, Bravo performed consistently whilst the field efficacy achieved by other modes of action declined; Bravo treatments appeared to improve by comparison such that by 2018 they were achieving disease control and yield responses that were broadly equivalent to the SDHIs (Imtrex and Vertisan).

4.1.2. Yellow rust

Disease control

High levels of yellow rust were observed at the trial site in 2015. Of the single-active products tested, Ignite and Comet (pyraclostrobin) performed similarly whilst Vertisan and Imtrex provided lower levels of control. Of the mixtures tested, those which contained epoxiconazole (Adexar, Keystone and Vertisan + Ignite) provided the highest levels of control. Ascra Xpro, Aviator Xpro and Priaxor (fluxapyroxad and pyraclostrobin) appeared to be broadly comparable to each other but with a slightly lower level of control compared to the treatments containing epoxiconazole (Figure 16).

Similarly high levels of disease were observed in 2016 at Terrington (site 11). Ignite (epoxiconazole) performed very well however Comet appeared marginally less effective. Again, the two SDHIs, Vertisan and Imtrex, appeared less effective, but still provided useful levels of yellow rust control. The SDHI-azoles (Ascra Xpro, Aviator Xpro, Keystone, Librax) and SDHI-strobilurin mixture (Priaxor) all reduced disease to a comparable level at full label rates, only being outperformed by Elatus Era (benzovindiflupyr + prothioconazole) (Figure 17).

In 2017, Ignite (epoxiconazole) again appeared to the most effective of the products with a single active substance. The remaining products in this category, Proline, Imtrex and Comet, all showed a similar level of yellow rust control. The SDHI mixtures tested all performed so similarly that no differences were distinguishable (Figure 18).

In 2018, hot weather in late May limited disease development and resulted in all the SDHI-azoles treatments appearing to be similarly effective (Figure 19). Some differences were observable between the products with a single active substance, with epoxiconazole showing strong activity, as consistent with previous seasons. Proline was also highly active, with Comet appearing to be less effective than these two azoles, but marginally better than Imtrex.

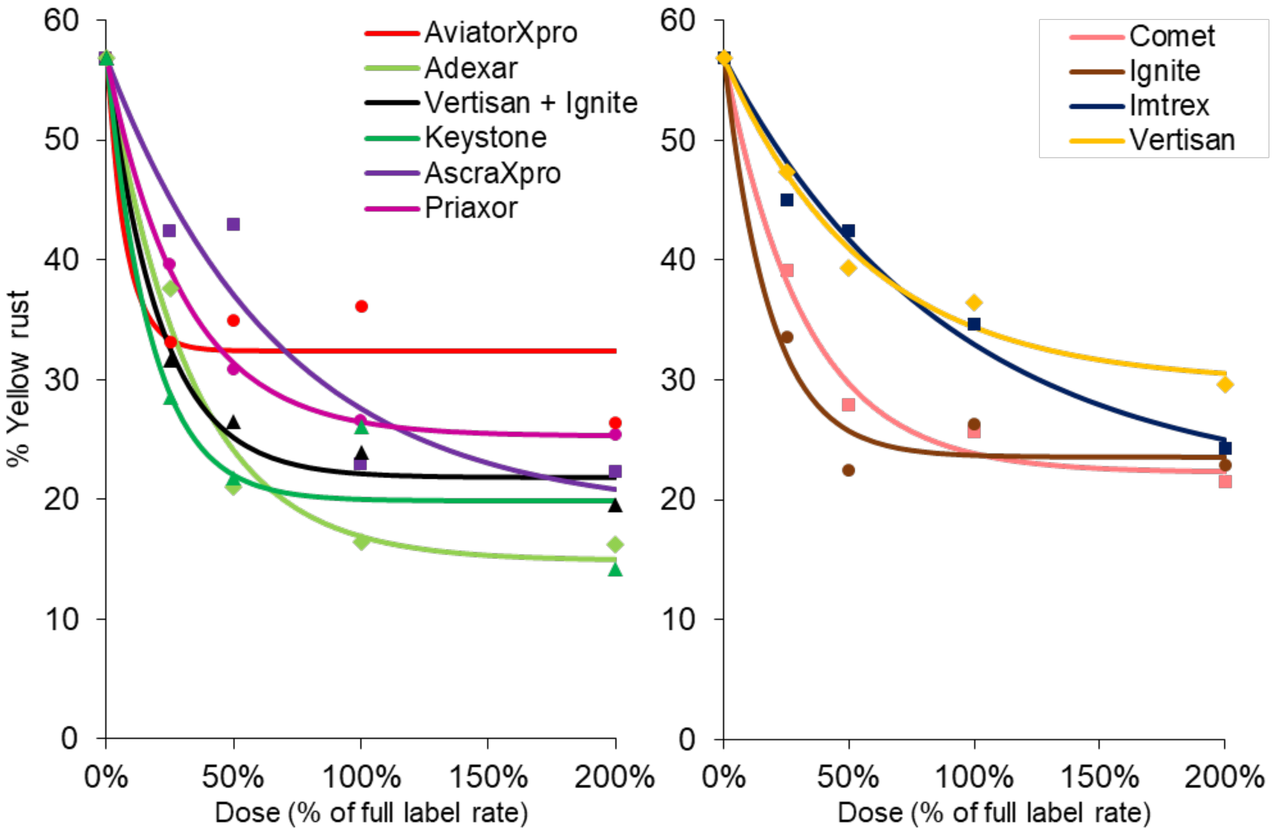

Figure 16: Fungicide dose-response curves for yellow rust control in 2015 (Terrington, site 4)

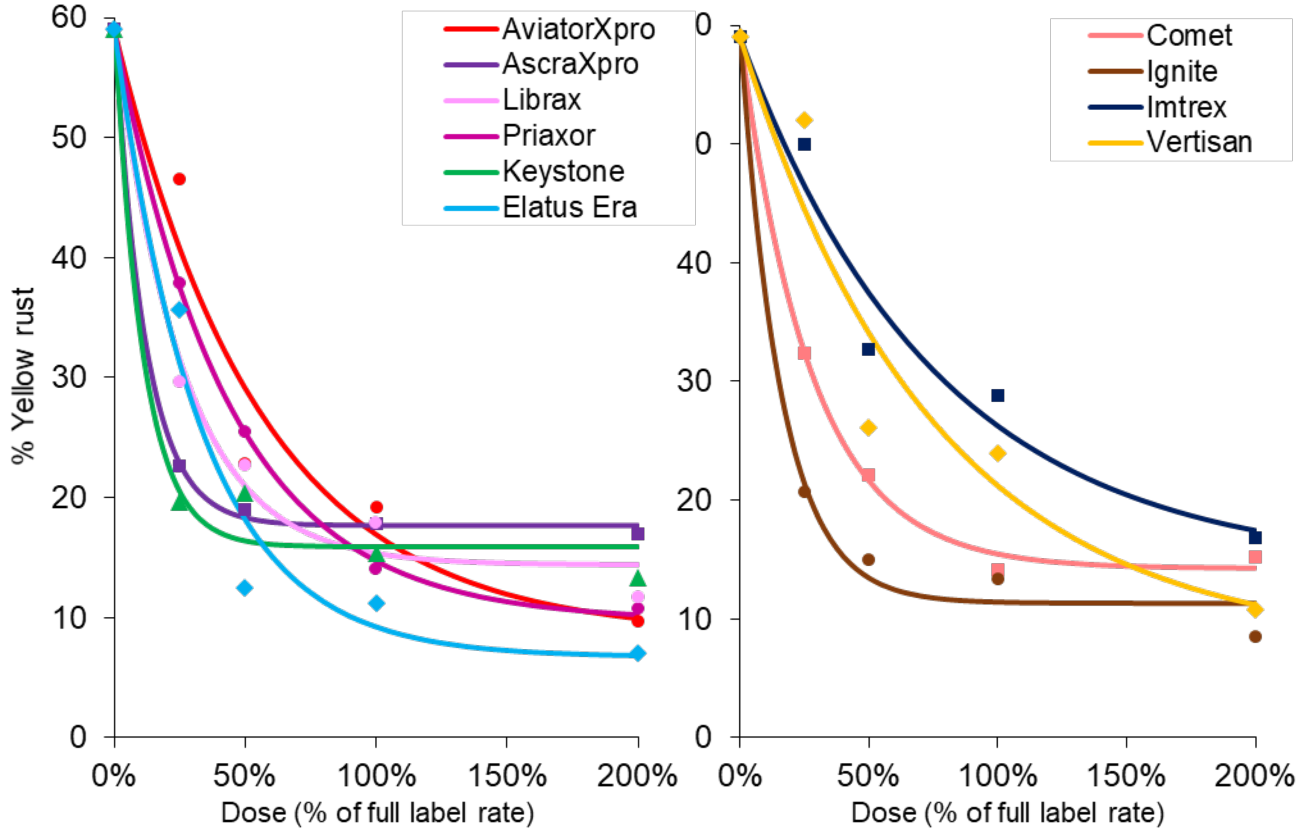

Figure 17: Fungicide dose-response curves for yellow rust control in 2016 (Terrington, site 11)

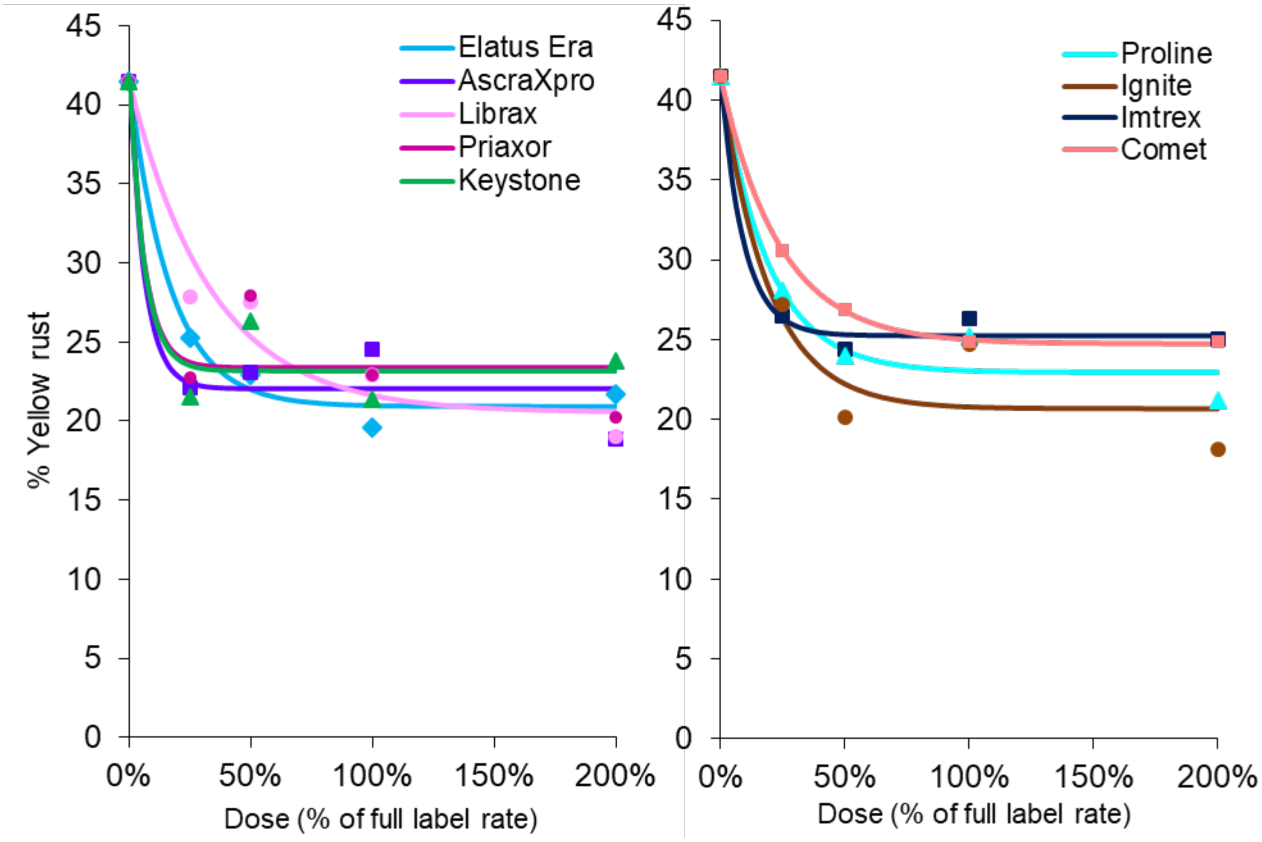

Figure 18: Fungicide dose-response curves for yellow rust control in 2017 (Terrington, site 19)

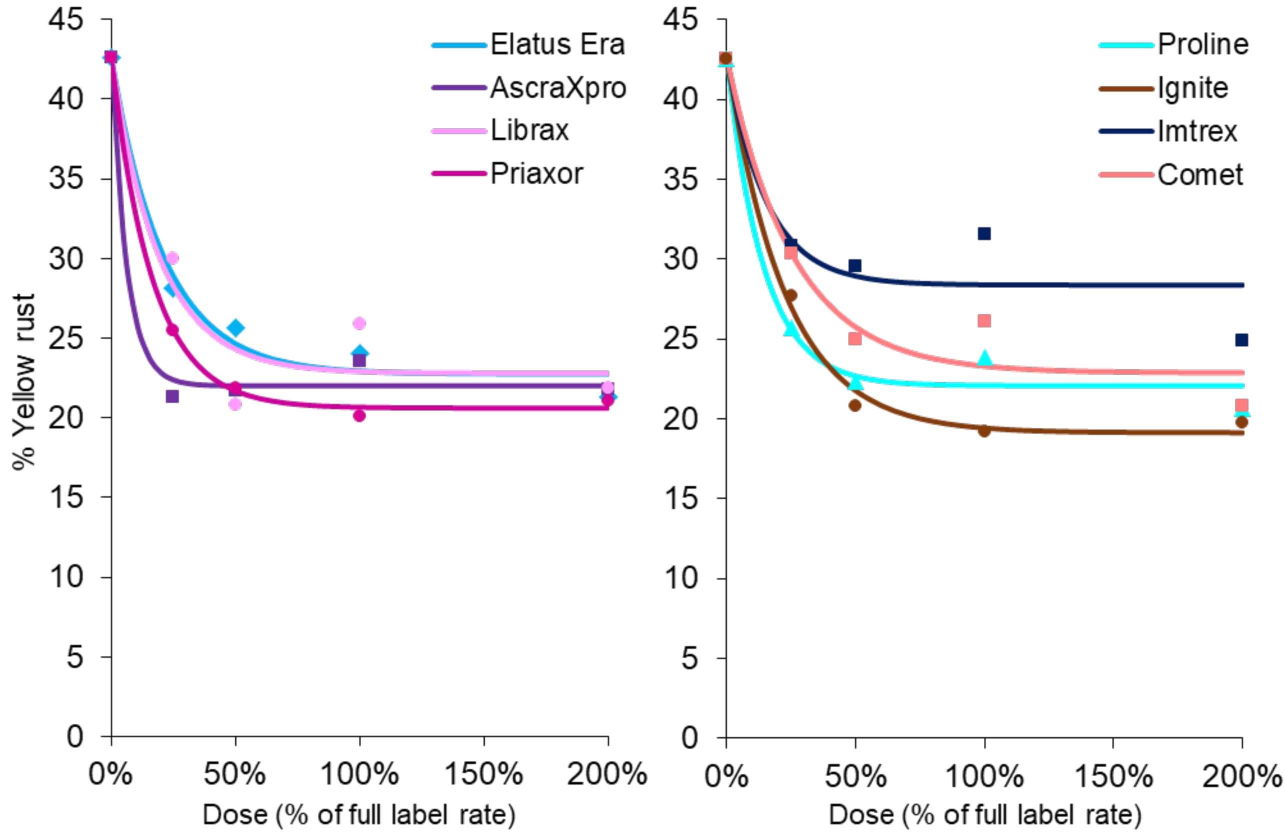

Figure 19: Fungicide dose-response curves for yellow rust control in 2018 (Terrington, site 27)

Yield

Yield losses due to yellow rust can be higher than for all other diseases due to the earliness and very damaging nature of the pathogen on highly susceptible varieties.

In 2015, at all doses, Imtrex and Vertisan produced the lowest yield responses, consistent with these treatments showing a lower level of disease control. Adexar, Keystone and Vertisan + Ignite performed the best, with a yield of around 5.0 t/ha at full dose rate, representing a yield response to treatment of 2.5 t/ha. Ascra Xpro, Aviator and Priaxor performed similarly, providing a yield response of between 1.0 and 1.5 t/ha. Of the products with a single active substance, Ignite was more effective than Comet despite the two showing similar levels of disease control at point of assessment (Figure 20).

In 2016, a single application of treatments generated yield responses of up to 4.0 t/ha over the untreated plots, which yielded around 3.04 t/ha (Figure 21). Keystone and Elatus Era produced the highest yield responses at all doses, followed by Ignite. The other mixed SDHI-azole treatments performed similarly, raising yields to ~5.5 t/ha. The straight SDHI’s, Imtrex and Vertisan showed the lowest yield responses (1.24 to 1.46 t/ha), and this was consistent with these treatments producing the least disease control.

Untreated yields in 2017 were high in comparison to 2015 and 2016, reflecting the lower levels of disease observed. At 100% dose, Elatus Era produced a higher yield response than all other treatments (2.35 t/ha) (Figure 22). The other SDHI mixture treatments performed similarly at a full label dose. Imtrex (a straight SDHI) and Comet (strobilurin) produced the lowest yield responses observed here (1.12 t/ha and 1.05 t/ha respectively at full dose), whereas Proline and Ignite were only outperformed by Elatus Era.

In 2018, Elatus Era treated plots again produced the highest yield response (1.50 t/ha) at full label rate; this was 0.4 to 0.45t/ha t/ha higher than Ascra Xpro and Librax. Priaxor, Proline and Ignite also showed positive yield responses at full rate applications, with Comet and Imtrex showing smaller improvements in yield, reflecting their lower activity on yellow rust (Figure 23).

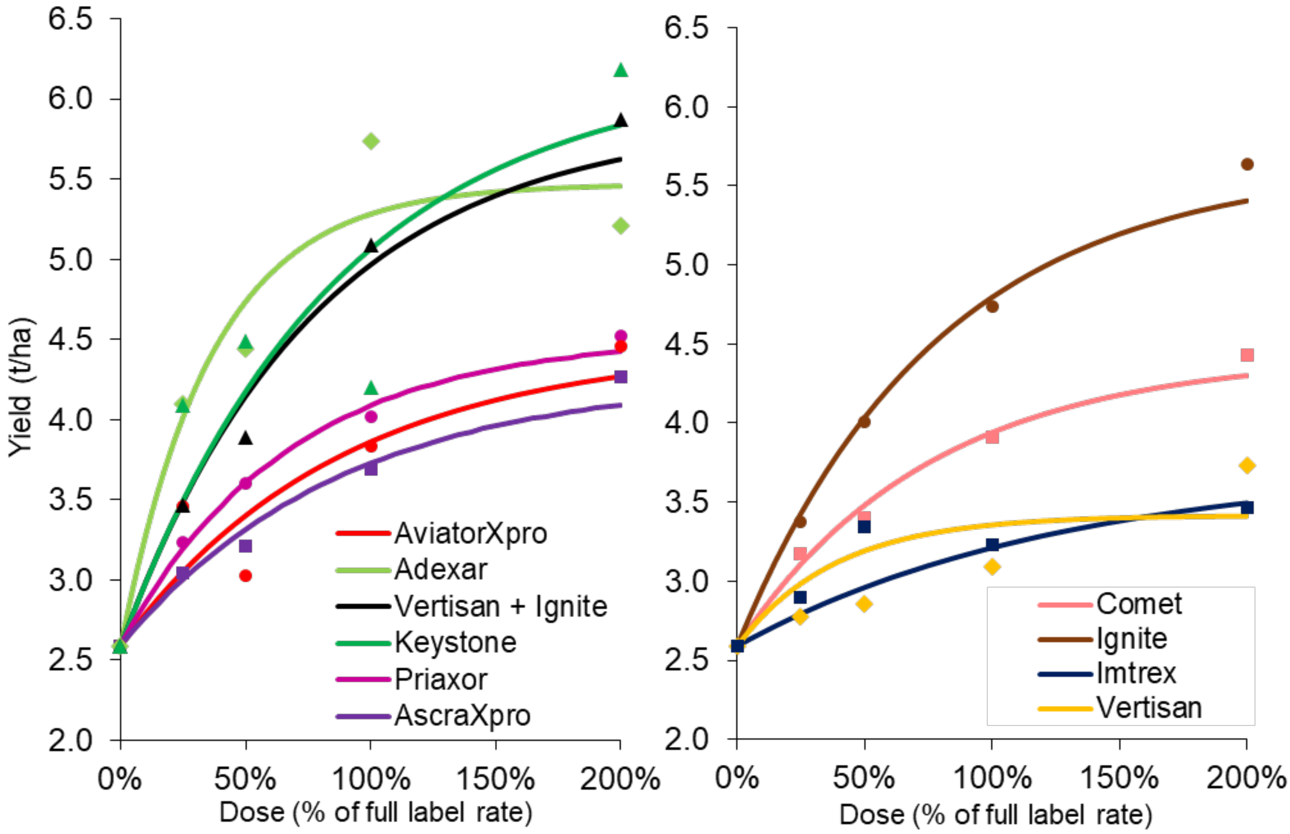

Figure 20: Fungicide dose-response curves for yield against yellow rust in 2015 (Terrington, site 4)

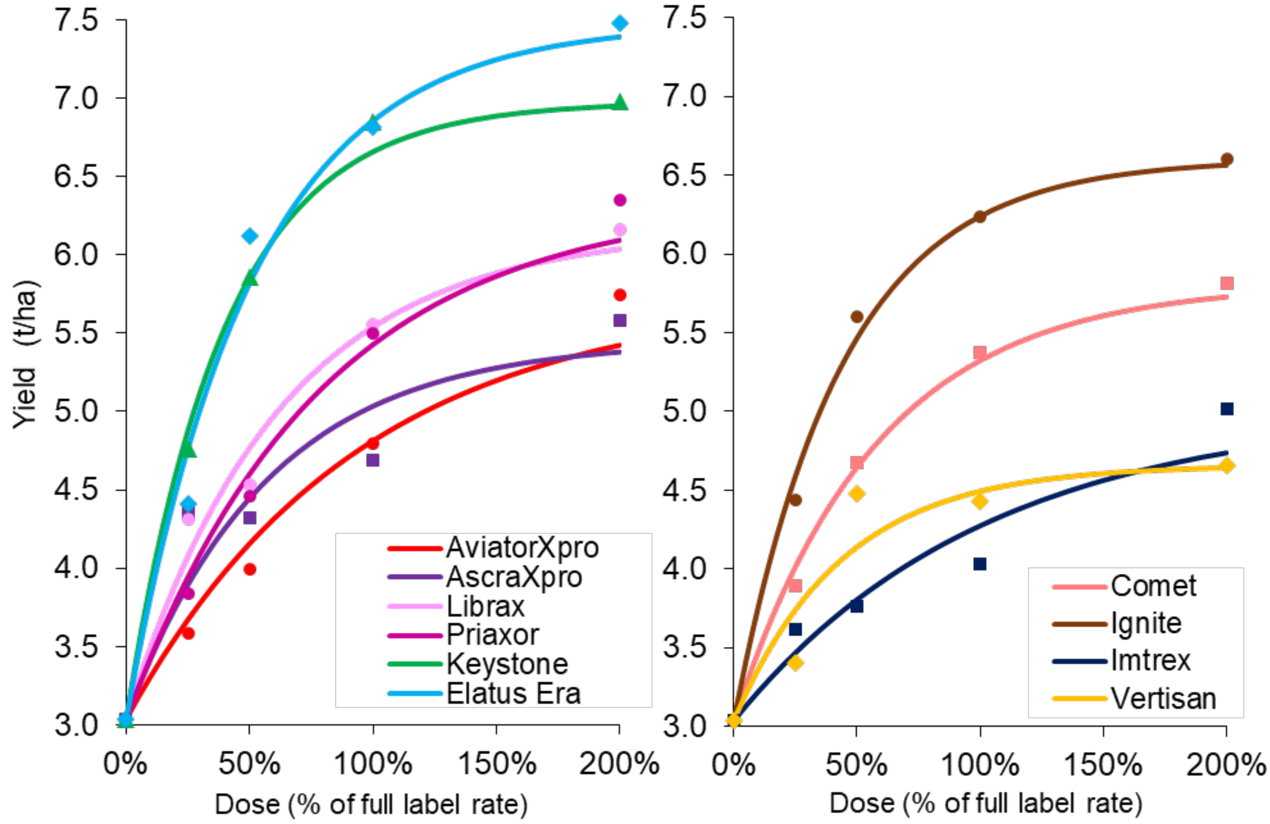

Figure 21: Fungicide dose-response curves for yield against yellow rust in 2016 (Terrington, site 11)

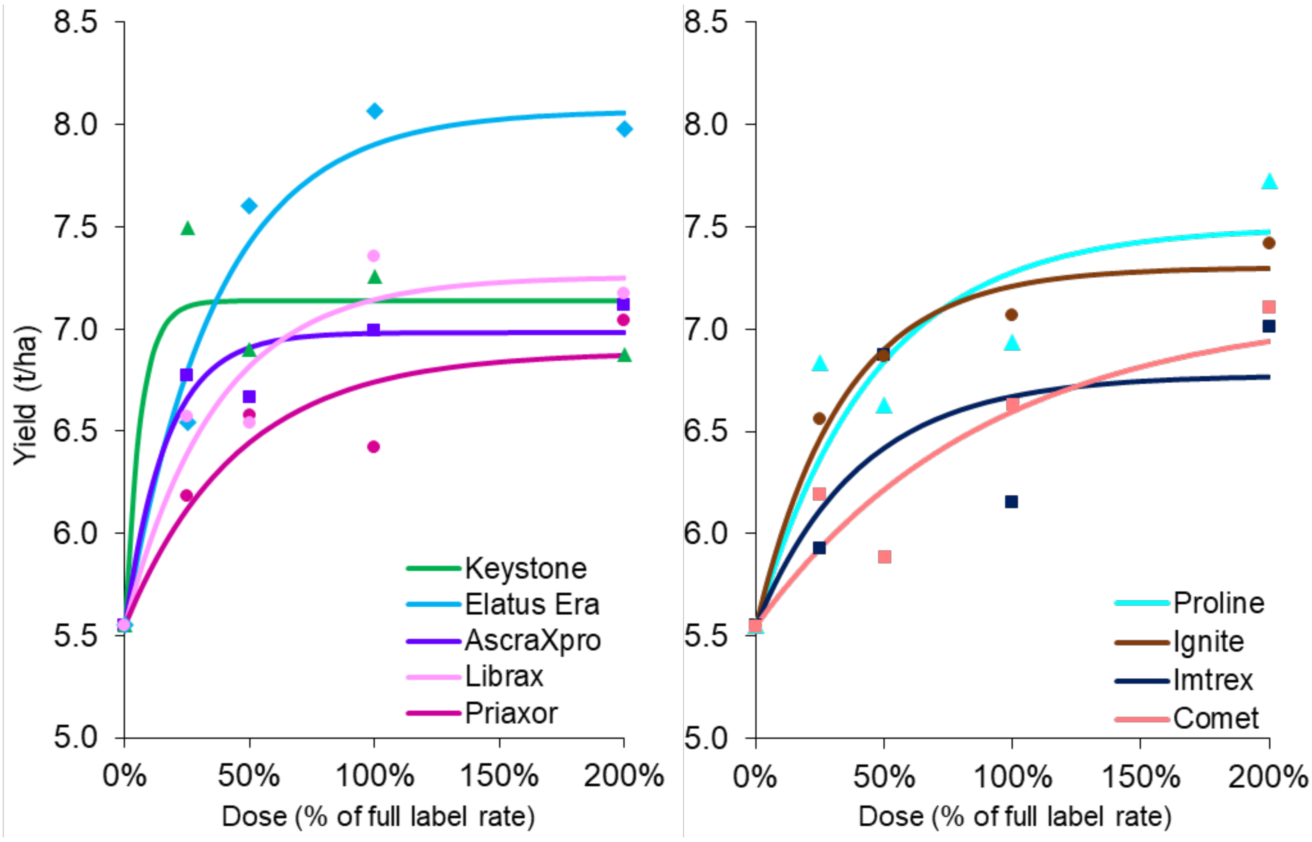

Figure 22: Fungicide dose-response curves for yield against yellow rust in 2017 (Terrington, site 19)

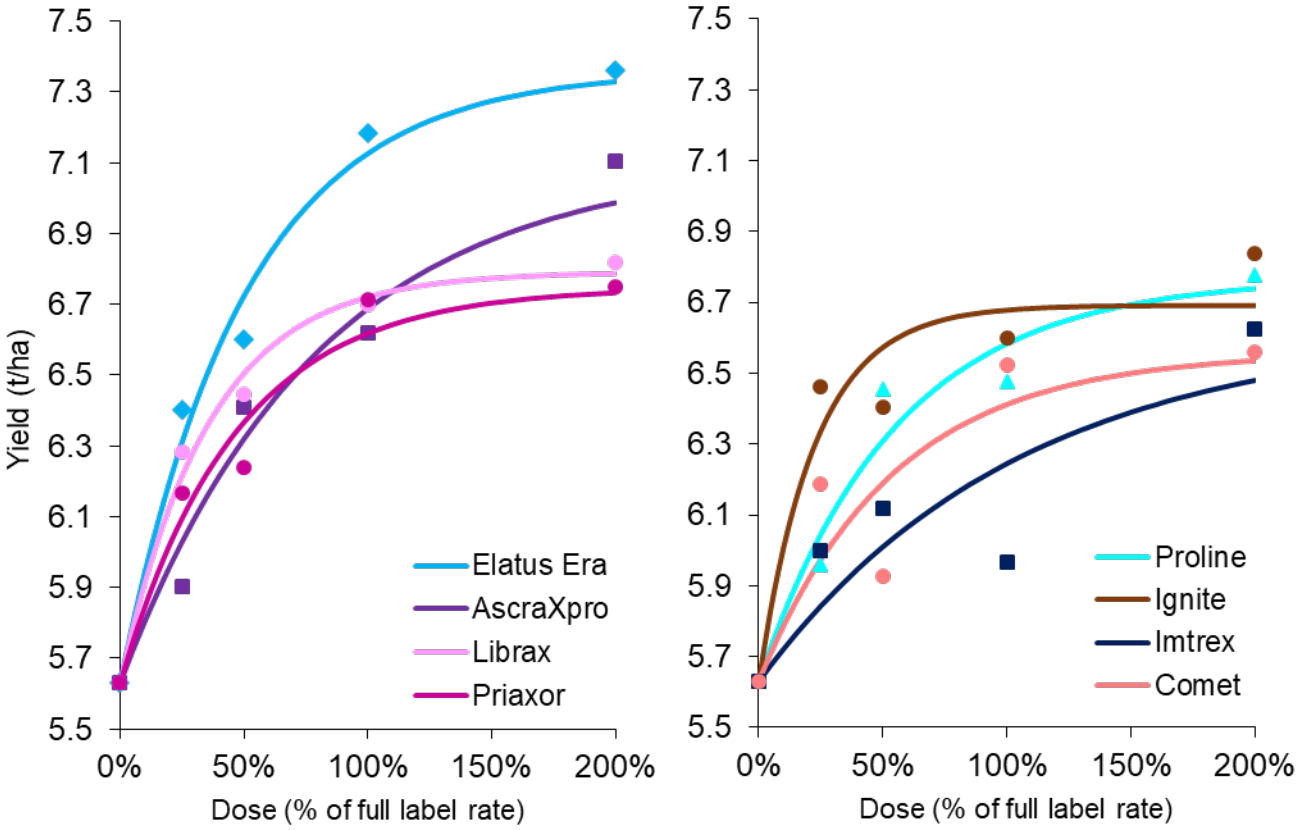

Figure 23: Fungicide dose-response curves for yield against yellow rust in 2018 (Terrington, site 27)

Summary

Across 2015 to 2018, the majority of treatments achieved good levels of disease control, with most products showing little benefit to increasing dose above 50% of label rates in terms of disease control. Although relative efficacy of different treatments varied between seasons, the straight triazole, Ignite, was consistently effective at controlling disease. Elatus Era, a treatment registered during the trial period, consistently out yielded other treatments showing comparable levels of disease control, suggesting that this treatment may be more persistent. The straight SDHIs, Imtrex and Vertisan, showed lower responses across all assessments described, whilst Comet, the one strobilurin tested here, appeared less effective than the azoles but ahead of the SDHIs in disease control and yield.

4.1.3. Brown rust

Disease control

All five products were tested in 2015 showed effective disease control, reducing brown rust levels from 28.3% to less than 5% at a full dose (Figure 24). Comet and Ignite appeared the most effective treatments with Caramba 90, another straight triazole, close behind. The straight SDHI treatments, Imtrex and Vertisan showed very good levels of brown rust control, performing only marginally less effective than Comet and Ignite.

There were lower levels of brown rust in 2016 trials and as a result, good disease control was seen at doses from 50% upwards for Caramba 90, Ignite and Vertisan, with a full rate application reducing disease to 0.29% or less. Vertisan showed the strongest responses at low doses and at a 25% dose, was the most effective treatment. Proline performed less well, reducing disease the least at all doses; Elatus Era reduced disease levels more than Proline, showing that the SDHI component, benzovindiflupyr adds activity to prothioconazole in the mixture (Figure 25).

In 2017, Proline provided very little control across all doses, whilst Vertisan and Caramba 90 showed much higher levels of control (Figure 26). The SDHI-azole mixture, Elatus Era, was the most effective treatment for controlling brown rust, fully controlling the disease where applied at doses above half rates.

Despite inoculation, disease levels were low at 6.28% in the untreated plots in 2018 (Figure 27). Elatus Era and Librax effectively controlled disease at all doses from 25%. Caramba 90 also showed good brown rust control and was similarly effective at full dose rates, whilst Proline displayed the lowest level of activity of the products tested, as in 2016 and 2017.

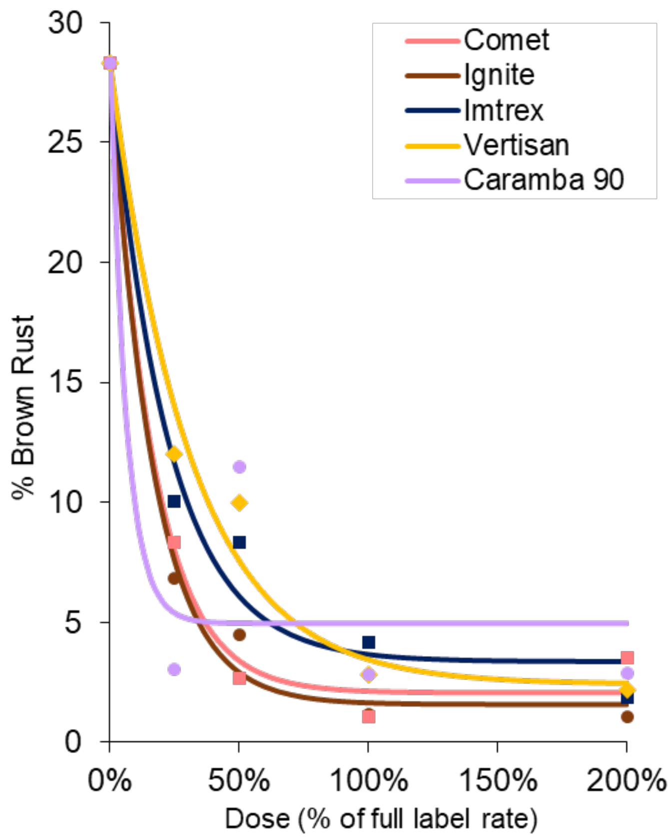

Figure 24: Fungicide dose-response curves for brown rust control in 2015 (Noon Folly, site 5)

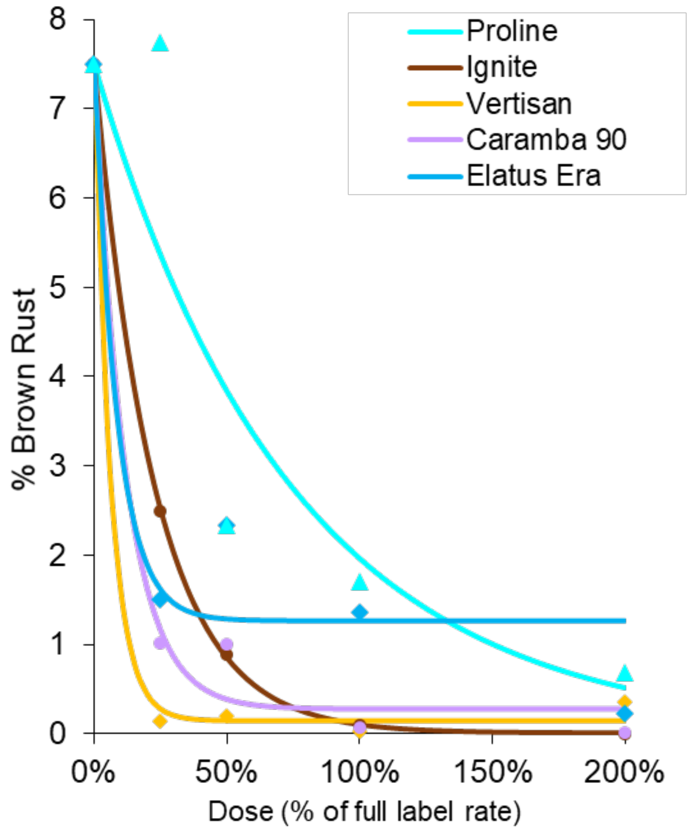

Figure 25: Fungicide dose-response curves for brown rust control in 2016 (Duxford, site 12)

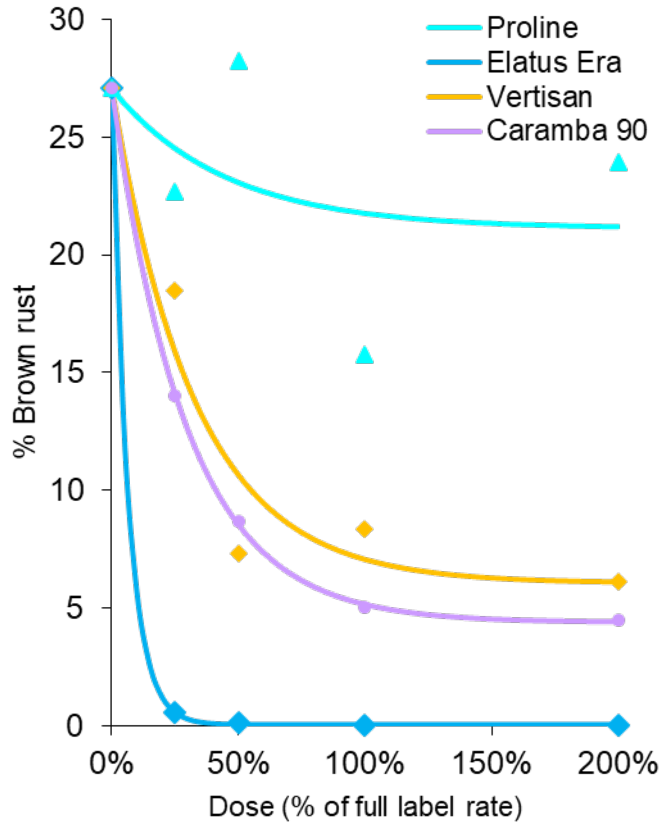

Figure 26: Fungicide dose-response curves for brown rust control in 2017 (Duxford, site 20)

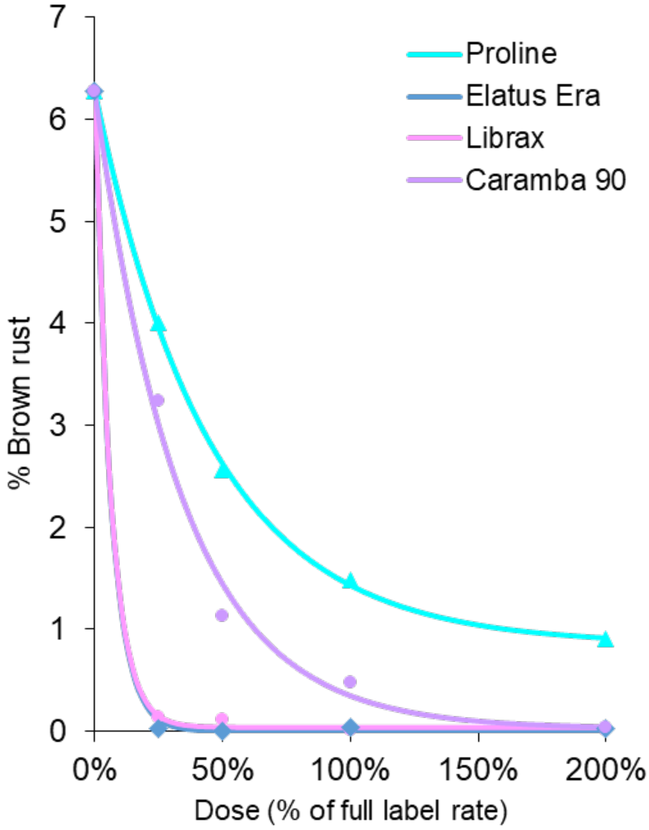

Figure 27: Fungicide dose-response curves for brown rust control in 2018 (Duxford, site 28)

Yield

Yield responses in 2015 were variable and inconsistent with the relative disease control of each treatment (Figure 28). Responses ranged from 0.39 t/ha (Vertisan) to 0.86 t/ha (Imtrex) at full dose rates (both straight SDHIs). Caramba 90, Comet and Ignite all produced similar yield responses, showing effective treatment at low doses (0.61 to 0.64t/ha at 25% dose rate), but little or no benefit by increasing dose above this. No trends were observable between the different modes of action.

In 2016, yields were low in the untreated plots due to high levels of disease late in the season (Figure 29). Proline recorded the lowest yield responses irrespective of dose (1.02 t/ha at full dose rate), with Elatus Era showing a small benefit from the addition of a mixture partner to prothioconazole. Caramba 90 and Ignite showed equal responses (2.20 and 2.26 t/ha respectively) at full dose, however unlike Ignite, Caramba 90 was as effective at a half dose (both straight triazoles). In contrast to the low yield response in 2015, Vertisan produced the greatest yield response (4.27 t/ha) at 100% rate.

As in 2016, Proline treatments provided only modest improvements in yield over the untreated in 2017 (~0.2 t/ha). This is reflective of the lower disease control observed compared to the other products tested. Elatus Era performed considerably better, producing the largest yield response observed (~1.8 t/ha) (Figure 30). No further benefit to yield or disease control was seen from applying

Elatus Era at rates over 50%. Vertisan and Caramba 90 provided good yield responses to treatment at full rates, with a yield response approximately half of that produced by Elatus Era.

In 2018 (site 28), data reflected that seen in the previous season, with Proline showing the lowest yield response at all doses (0.72 t/ha at full rate) and Elatus Era showing the largest yield response (1.60 t/ha at full dose). Despite showing similar levels of disease control, Elatus Era treated plots out yielded those treated with Librax; neither treatment showed an improvement in yield to increasing dose above 25%. Caramba 90 showed useful levels of activity and yield improvements of over 1.0 t/ha at a full rate application.

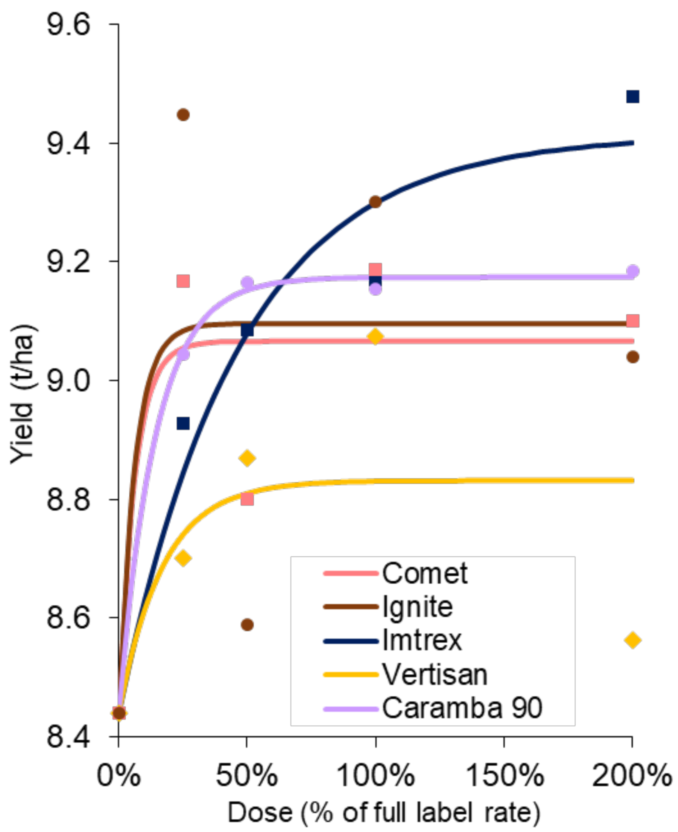

Figure 28: Fungicide dose-response curves for yield in brown rust trials in 2015 (Noon Folly, site 5)

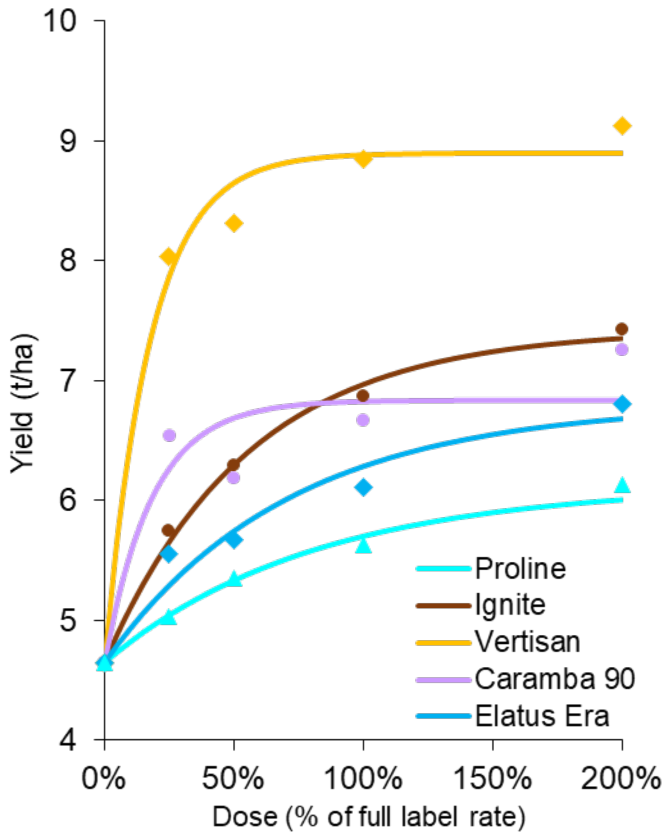

Figure 29: Fungicide dose-response curves for yield in brown rust trials in 2016 (Duxford, site 12)

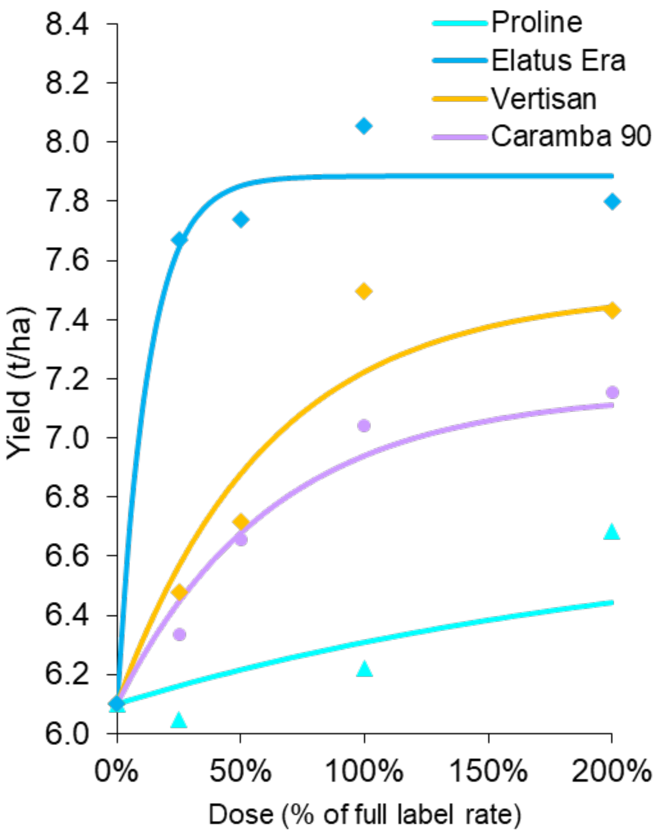

Figure 30: Fungicide dose-response curves for yield in brown rust trials in 2017 (Duxford, site 20)

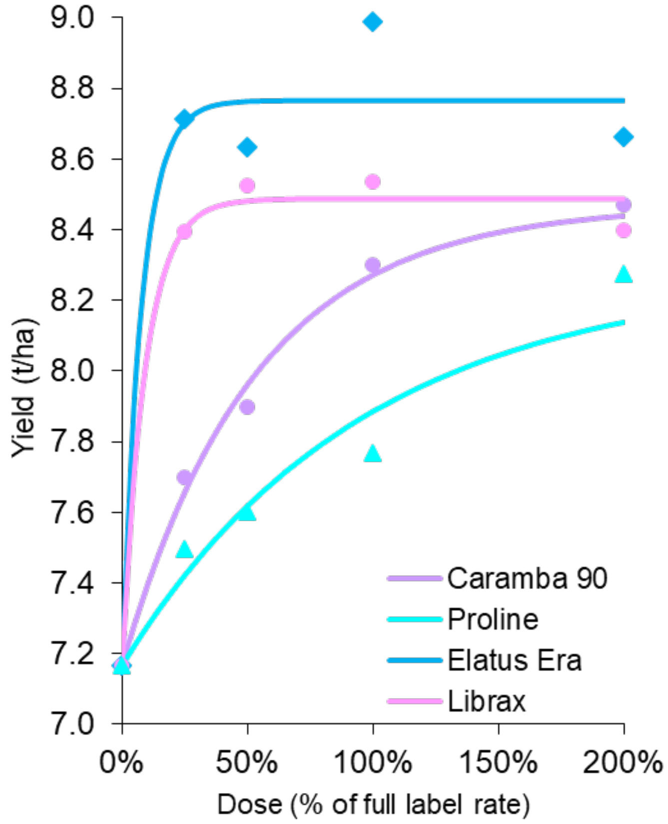

Figure 31: Fungicide dose-response curves for yield in brown rust trials in 2018 (Duxford, site 28)

Summary

Brown rust trials (as with yellow rust trials) showed variation in the rank order of product activity between seasons, for example, Vertisan enhanced yield the most in 2016 but least in 2015. Across the seasons, there appeared to be no consistent trends separating straight SDHIs from the SDHI mixtures, however Proline (straight azole) was consistently less effective compared to other treatments at controlling disease and improving yield. Elatus Era performed well, indicating that benzovindiflupyr has a high level of activity on brown rust.

4.1.4. Head blight

Disease control

Head blight incidence of 16.3% in the untreated control were obtained in the trial at Gleadthorpe (site 6) in 2015 (Figure 32). Although the data in this trial are noisy, all treatments reduced disease and Caramba 90, Folicur (tebuconazole) and Ignite appeared to perform with equivalent efficacy. Proline showed a higher level of activity.

In 2016, disease pressure was considerably higher than in other years (Figure 33). Although Proline again appeared to be the most effective treatment, activity achieved by Ignite and Folicur at full doses was comparable. Caramba 90 showed slightly lower levels of control at 100% doses, although still provided effective reduction.

Proline again appeared to have the highest level of activity in 2017 (Figure 34), although Folicur provided equivalent control at half rate applications. There was no apparent benefit to increasing doses of Folicur above 50% of full label rate, with a full dose showing equal reduction in disease to Caramba 90. Ignite appeared to have a lower level of activity overall.

Two different treatments were included in the trials at site 29 in 2018, Soleil (bromuconazole + tebuconazole) and Unizeb Gold (mancozeb). At 50% and 100% doses, Soleil showed control similar to that provided by Folicur and as such, it is difficult to determine the benefit provided by bromuconazole in the mixture as tebuconazole is present at different concentrations in the two products. Proline also performed similarly. Unizeb Gold controlled head blight symptoms, but didn't quite achieve the same level of activity as other products tested here (Figure 35).

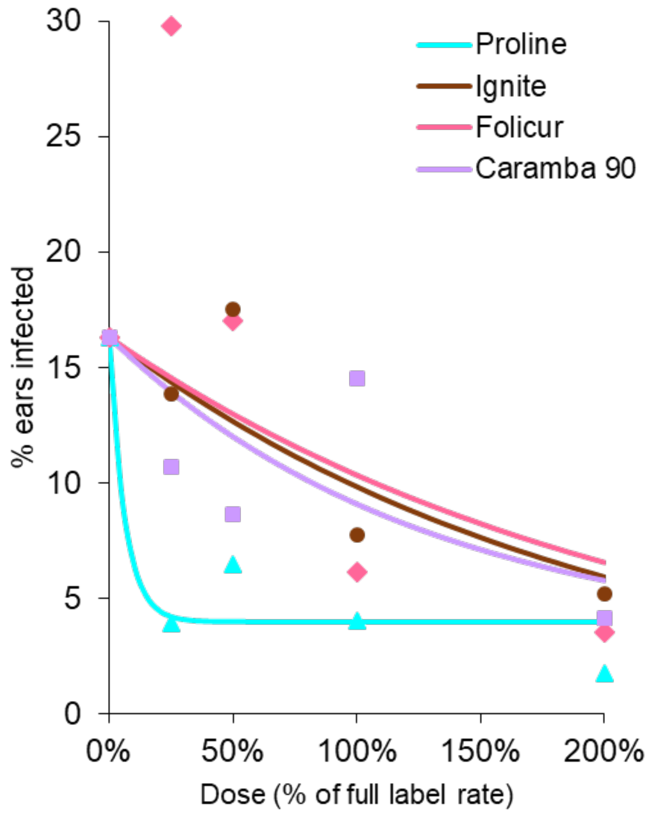

Figure 32: Fungicide dose-response curves for control of head blight in 2015 (Gleadthorpe, site 6)

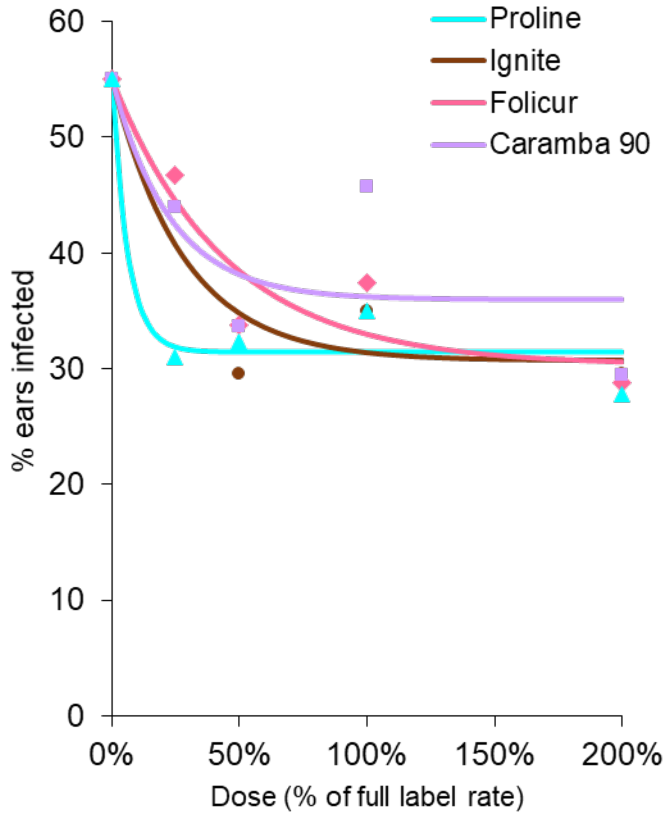

Figure 33: Fungicide dose-response curves for control of head blight in 2016 (Gleadthorpe, site 13)

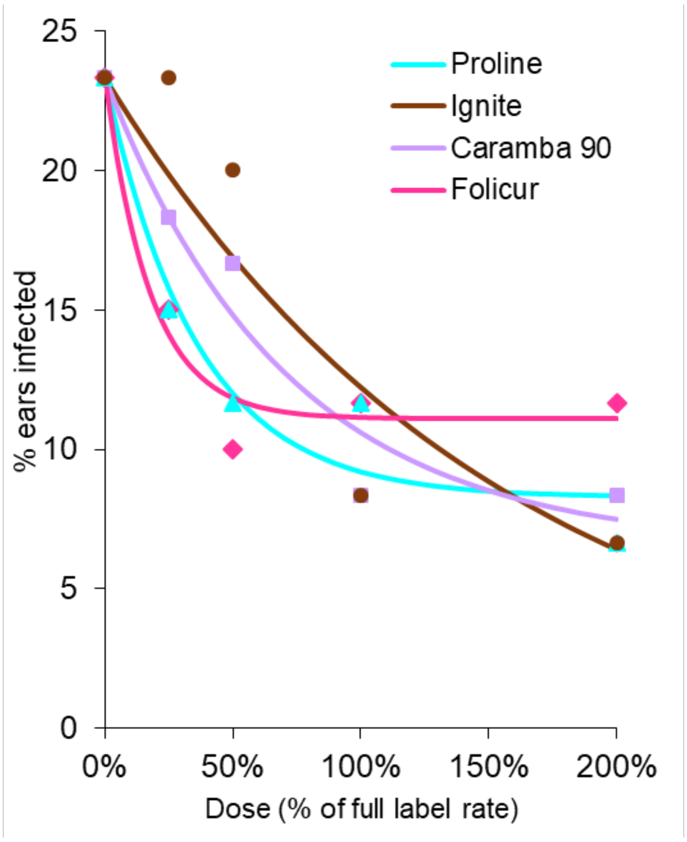

Figure 34: Fungicide dose-response curves for control of head blight in 2017 (Gleadthorpe, site 21)

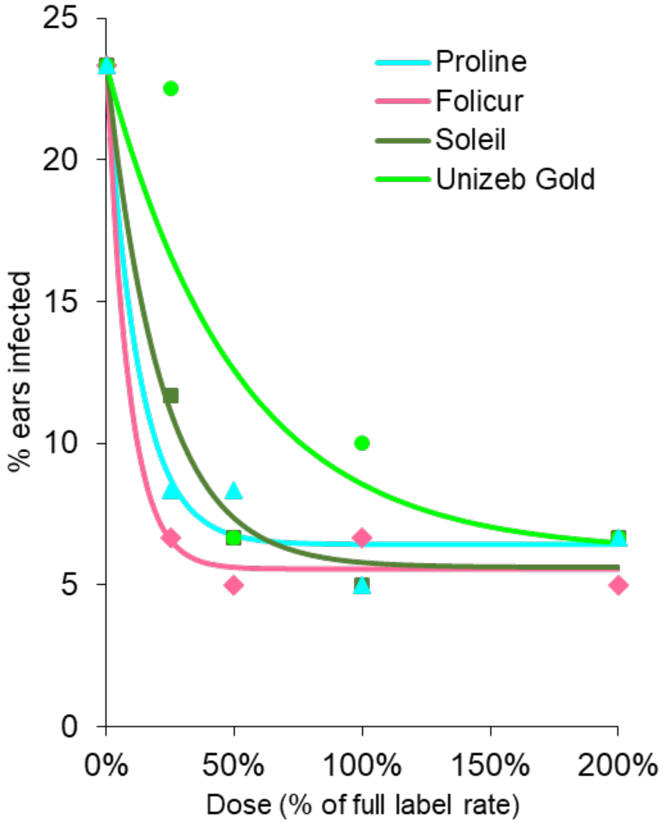

Figure 35: Fungicide dose-response curves for control of head blight in 2018 (Gleadthorpe, site 29)

Molecular analysis

Molecular analysis was used to quantify DNA levels (in pg/ng total DNA) of *Fusarium* species and *Microdochium nivale*. Both pathogens may be responsible for the visual symptoms of head blight, however *M. nivale* does not produce deoxynivalenol mycotoxin.

In 2015, readings of *Fusarium* DNA were approximately 10 times greater than *Microdochium* DNA. All treatments showed higher *Microdochium* levels than the untreated control, however all treatments significantly reduced *Fusarium* DNA and DON levels (Figure 36). Ignite provided the greatest reduction in both DNA and DON levels. Consistent with the strong reduction in visual symptoms, Proline also reduced *Fusarium* DNA and DON levels effectively. This evidence suggests that *Fusarium* spp. were responsible for head blight symptoms observed.

Again in 2016 (Figure 37), all trials contained more *Microdochium* DNA than both of the untreated controls. The relative responses of each treatment on reduction of *Fusarium* DNA and DON levels suggests that again, *Fusarium* spp. were mainly responsible for the disease observable. As is consistent with the reduction in ear blight displayed in Figure 33, Folicur and Proline reduced both DON and *Fusarium* DNA by a similar proportion. In contrast, Ignite was less effective at reducing DNA and DON and Caramba 90 showed greater reduction in DNA and DON levels than in visual symptoms.

In 2017, in contrast to previous years, *Microdochium* DNA levels were much higher than *Fusarium* DNA. All treatments provided effective control of *Fusarium* DNA and DON and although the treatments reduced *Microdochium* DNA in comparison to the untreated, the reduction was relatively less than that of *Fusarium* DNA or DON. No consistent trends could be observed between the reduction in visible symptoms and the molecular analyses (Figure 38).

Two untreated samples were analysed separately for DNA in 2018 (Figure 39) and although the Untreated 2 sample contained less pathogen DNA than Untreated 1, both showed approximately three times more *Fusarium* DNA than *Microdochium* DNA. All treatments reduced pathogen DNA compared to the Untreated 1 sample, with Soleil showing the greatest reduction in *Fusarium* DNA. Consistent with the lower control of observable symptoms, Unizeb Gold showed the less control of *Fusarium* DNA, however produced a larger decrease in *Microdochium* DNA (reducing disease to 31.4% of Untreated 1) relative to *Fusarium* DNA (82.7% of Untreated 1). DON levels are not reported as they were below the limit of quantification. The lack of quantifiable DON (<200 ppb) despite equivalent *Fusarium* DNA compared to previous years would indicate that the hot dry summer of 2018 was not conducive to DON production even when *Fusarium* infection had occurred.

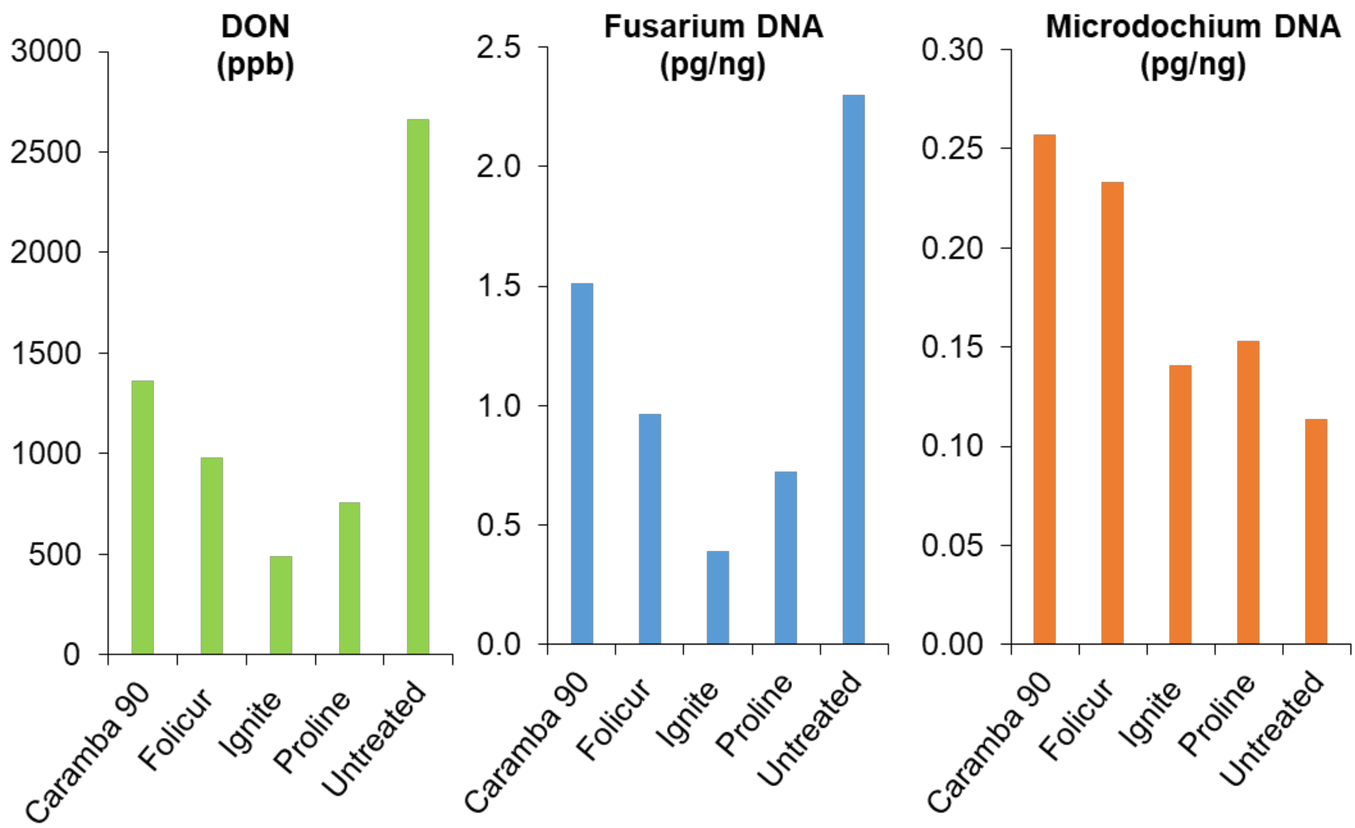

Figure 36: Molecular analysis of DNA and DON levels in response to fungicides in 2015 (Gleadthorpe, site 6)

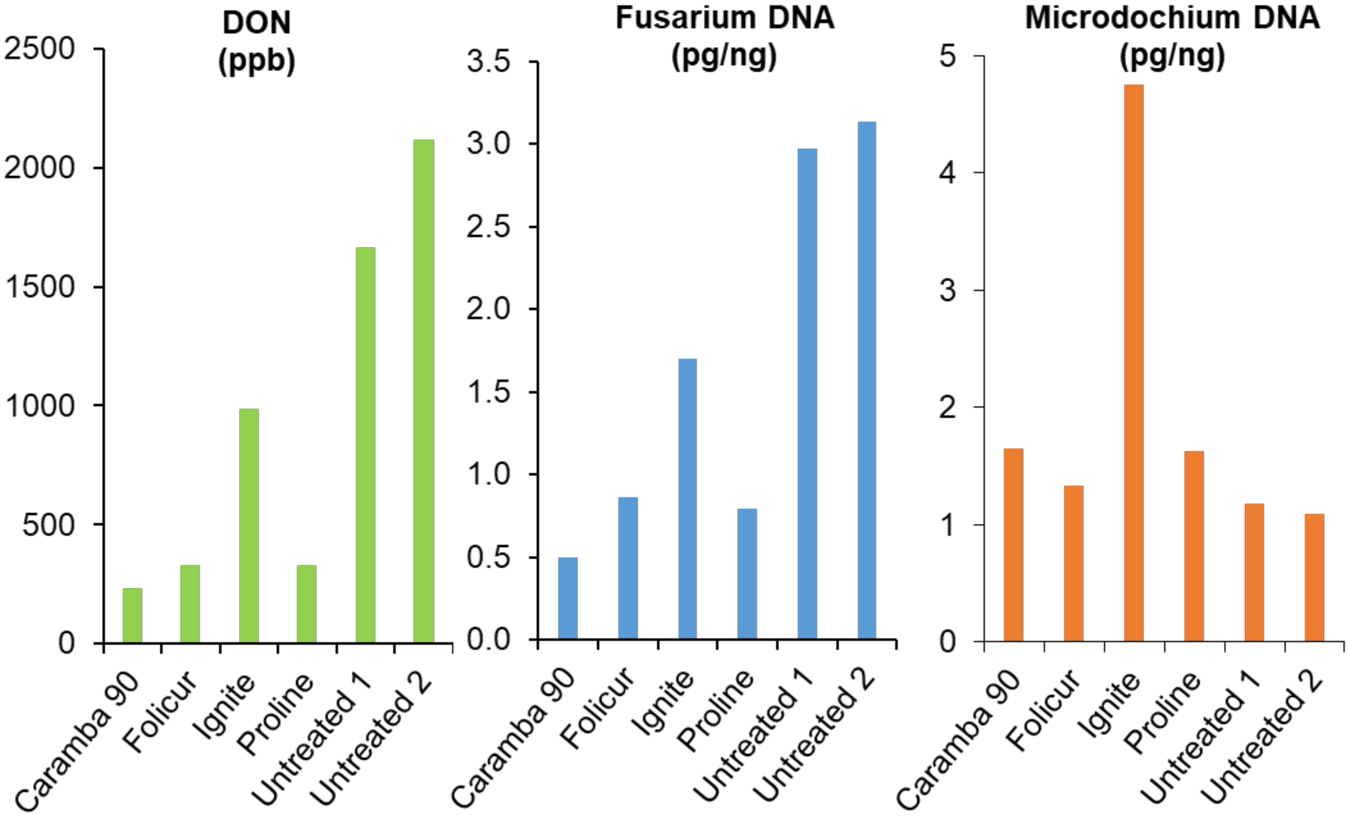

Figure 37: Molecular analysis of DNA and DON levels in response to fungicides in 2016 (Gleadthorpe, site 13)

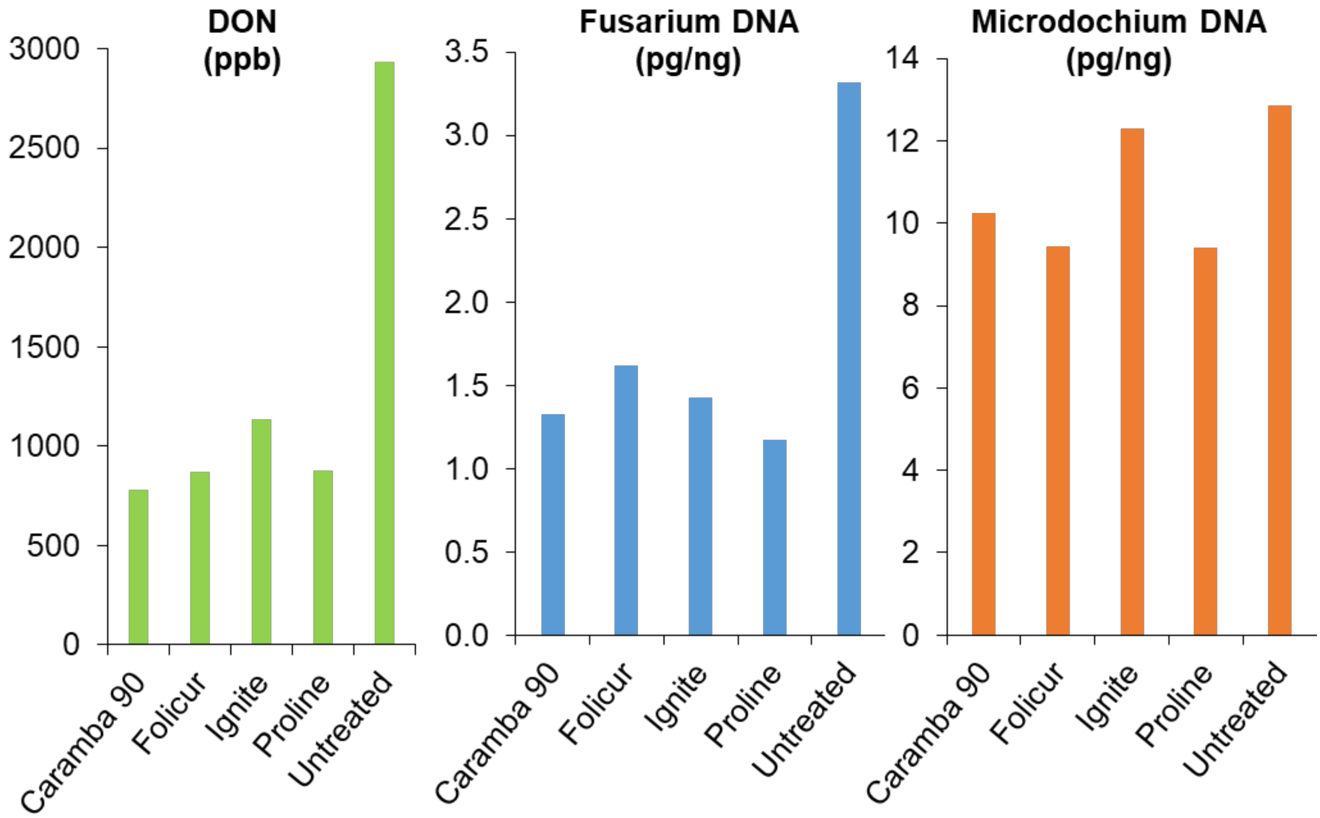

Figure 38: Molecular analysis of DNA and DON levels in response to fungicides in 2017 (Gleadthorpe, site 21)

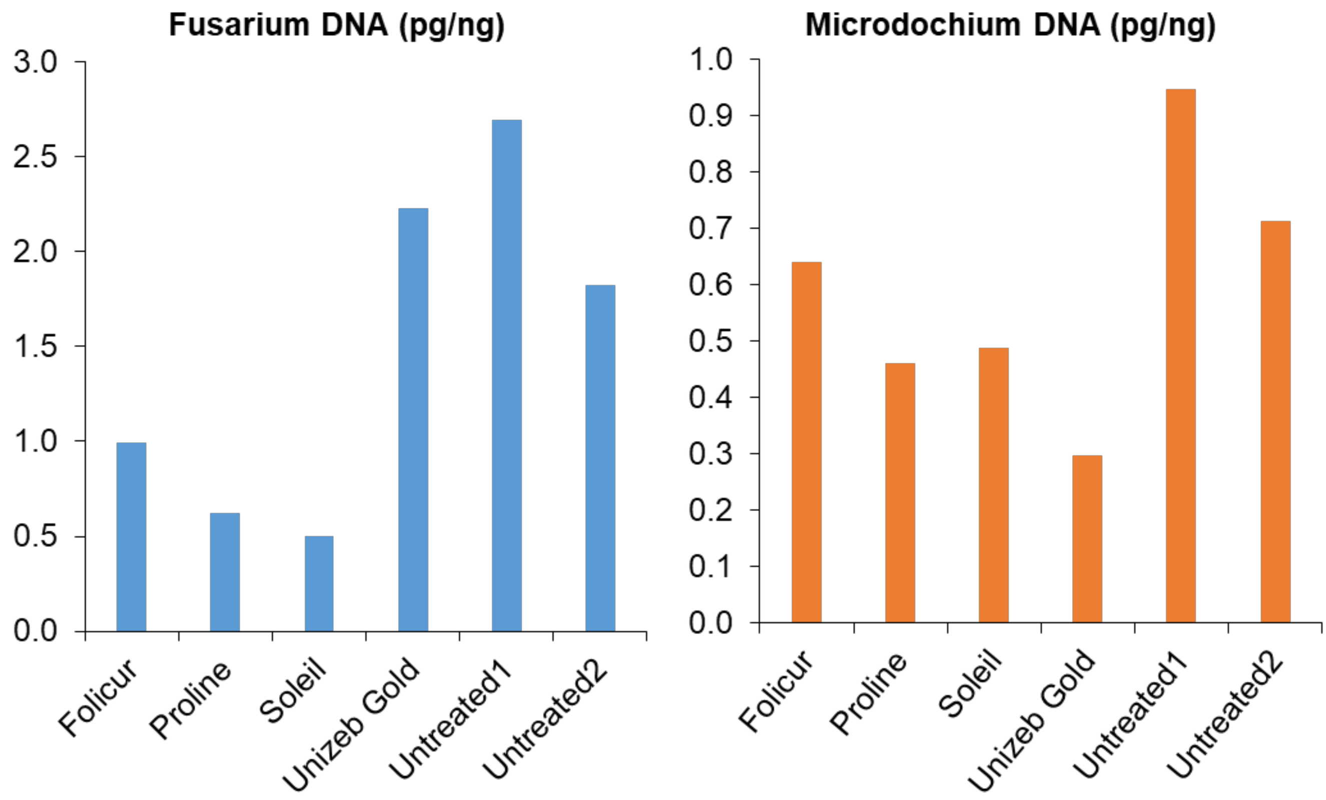

Figure 39: Molecular analysis of DNA levels in response to fungicides in 2018 (Gleadthorpe, site 29)

Summary

Across all seasons, it is likely that *Fusarium* spp. were primarily responsible for visible head blight symptoms, with relative efficacies between treatments in disease reduction matching *Fusarium* DNA and DON levels. In all years the mean concentration of DON in the untreated controls was above the legal limit of 1250 ppb for wheat intended for human consumption. All fungicides, applied at full rate, reduced the mean DON concentration to below the legal limit except Caramba 90 in 2015 when the mean DON was reduced to 1361 ppb. Proline provided consistently good control of visible ear blight as well as reducing pathogen DNA and DON to levels equivalent to, or less than other treatments and the untreated sample/s. Unizeb Gold, tested in the 2018 season only, appeared to provide stronger control of head blight caused by *Microdochium* spp. than *Fusarium* spp.

4.2. Barley

4.2.1. Rhynchosporium

Disease control

In 2015, at a full dose, Proline, Imtrex, Adexar, Priaxor and Siltra Xpro (bixafen + prothioconazole) showed the greatest levels of protectant activity (Figure 40). Adexar, Imtrex and Priaxor (all containing fluxapyroxad), alongside Proline and Siltra Xpro (both containing prothioconazole) showed the strongest responses. Comet, Vertisan and Zulu (isopyrazam) had less activity at all doses.

In 2016, Elatus Era, Siltra Xpro and Priaxor (SDHI-based mixtures) showed the greatest levels of protectant activity, performing only slightly better than Proline and Imtrex. The timing of fungicide application and early disease progression meant that curative activity of the treatments could also be assessed in 2016, with high levels of rhynchosporium present in the untreated plots at the assessment timing. Trends were consistent between protectant and curative situations, with Comet showing the lowest levels of control of the treatments tested (Figure 41 and Figure 42).

In the 2017 trials (Figure 43), straight products were less effective than mixtures, with Proline being the most effective of the straights tested and Comet and Vertisan being the least effective. An exception to this trend was Imtrex (straight SDHI), which performed as well as Siltra Xpro, Elatus Era (SDHI-prothioconazole mixtures) and Priaxor (SDHI-strobilurin mixture).

The data obtained in 2018 broadly reflected the trends seen in previous years, although average disease pressure was lower (Figure 44). Siltra Xpro and Imtrex were most effective, although Elatus Era and Proline also showed strong disease control. Again, Comet showed a lower activity in comparison to other straights.

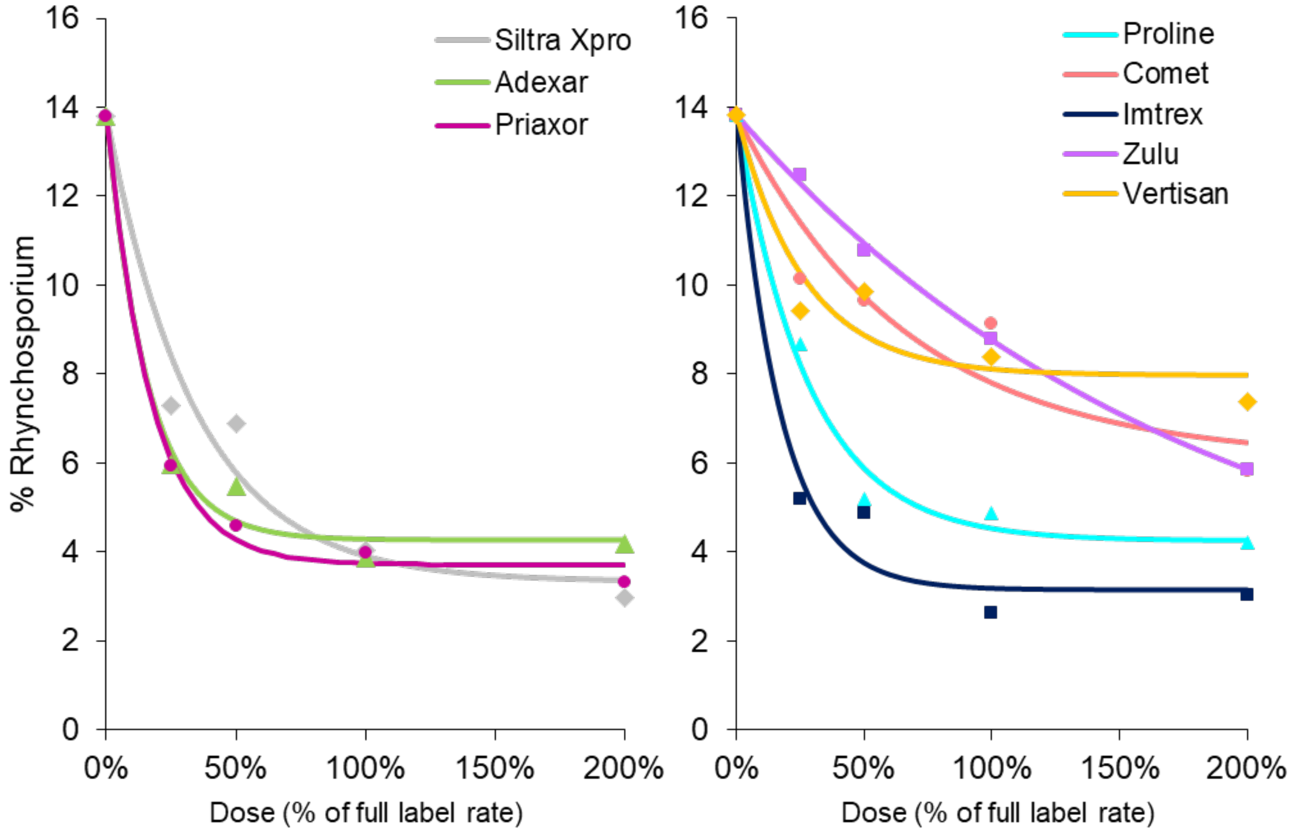

Figure 40: Fungicide dose-response curves for protectant activity against rhynchosporium in 2015 (mean of three trials)

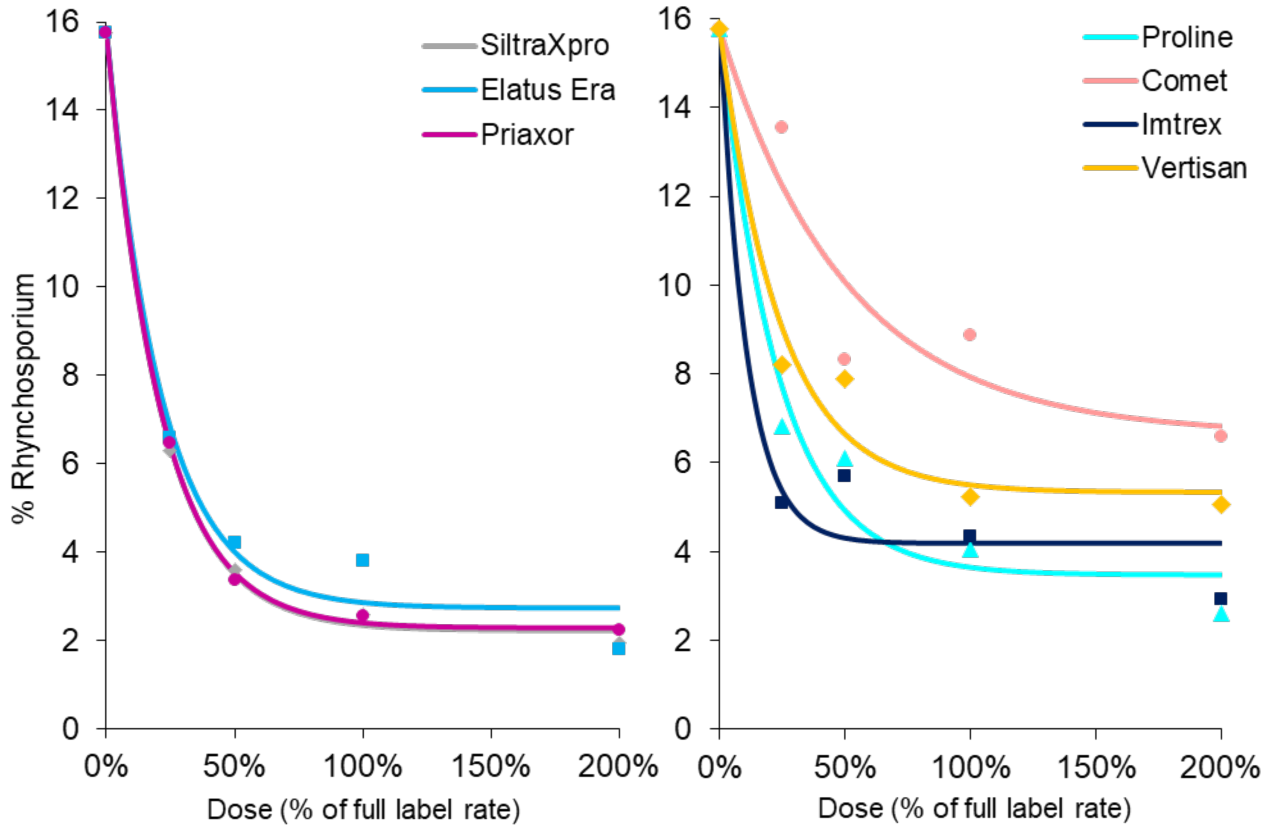

Figure 41: Fungicide dose-response curves for protectant activity against rhynchosporium in 2016 (mean of three trials)

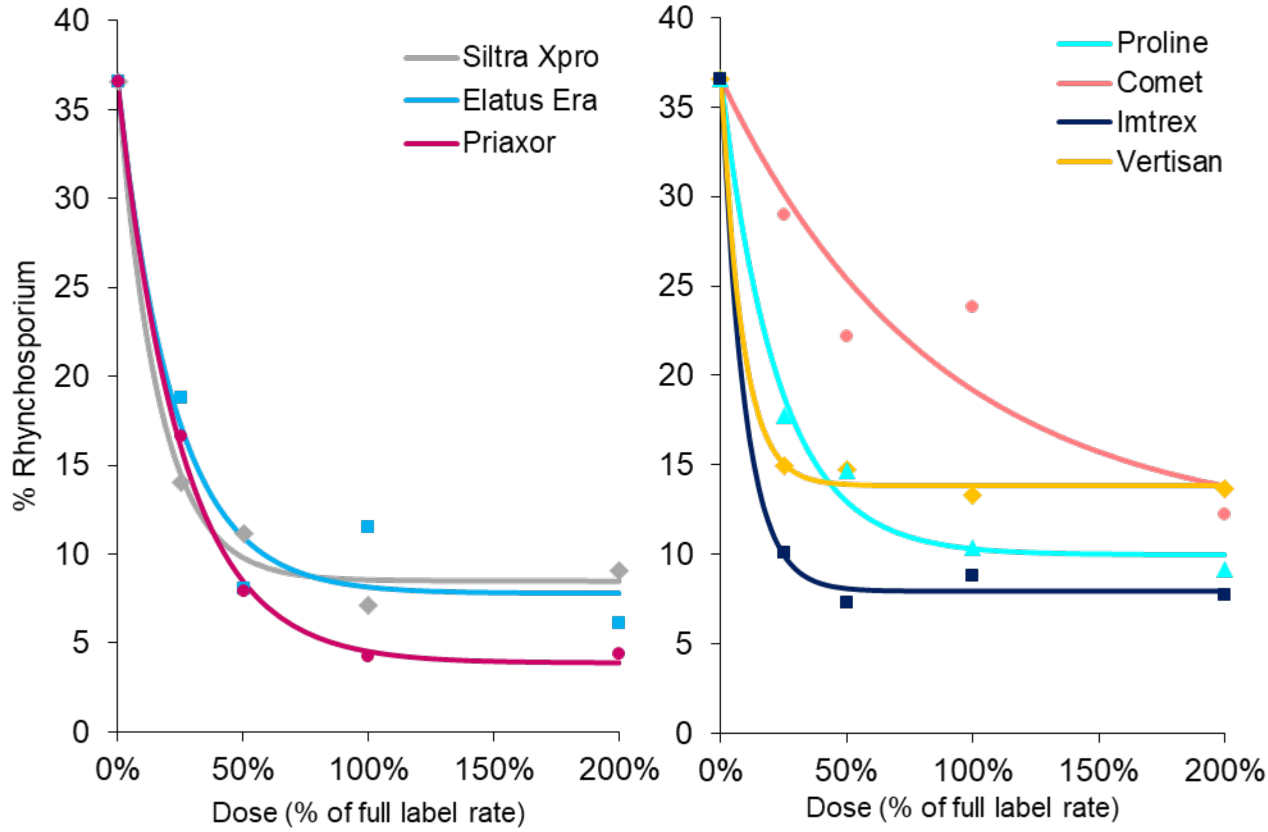

Figure 42: Fungicide dose-response curves for curative activity against rhynchosporium in 2016 (mean of three trials)

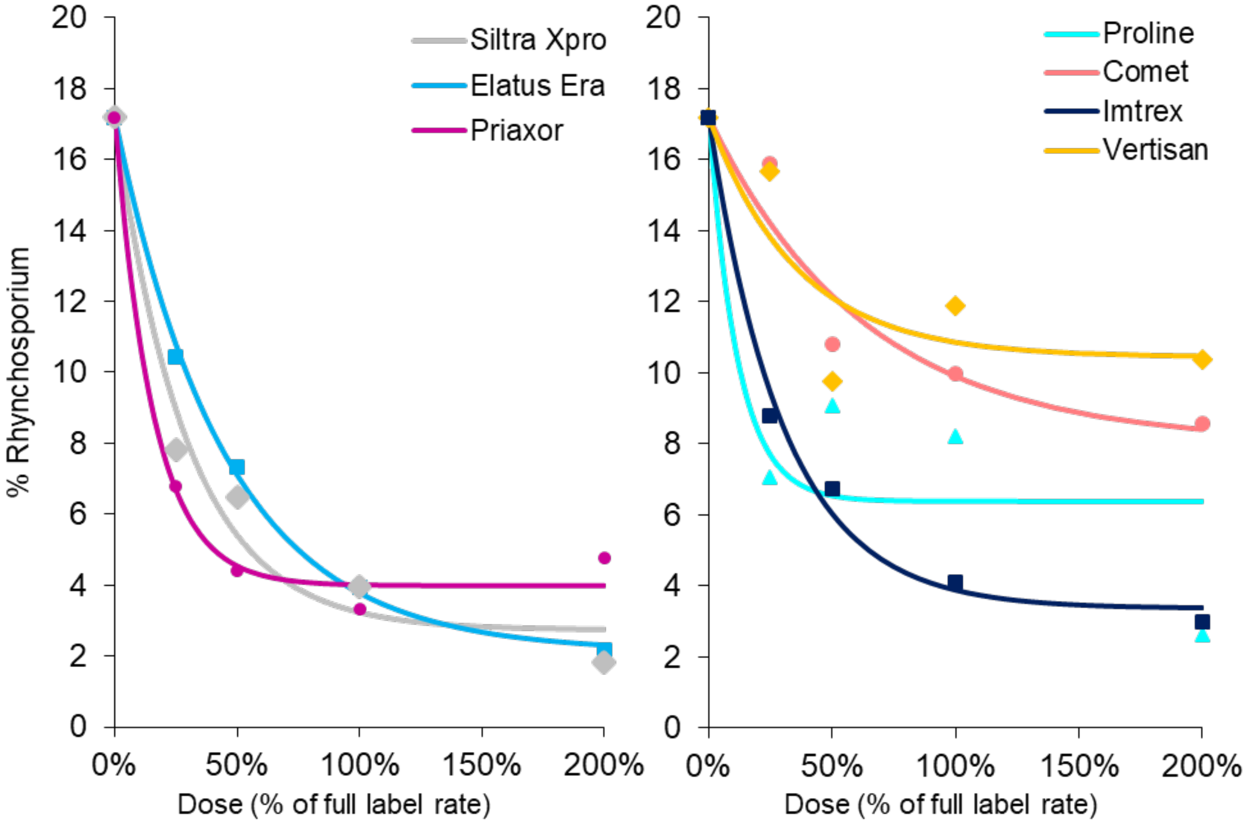

Figure 43: Fungicide dose-response curves for protectant activity against rhynchosporium in 2017 (mean of three trials)

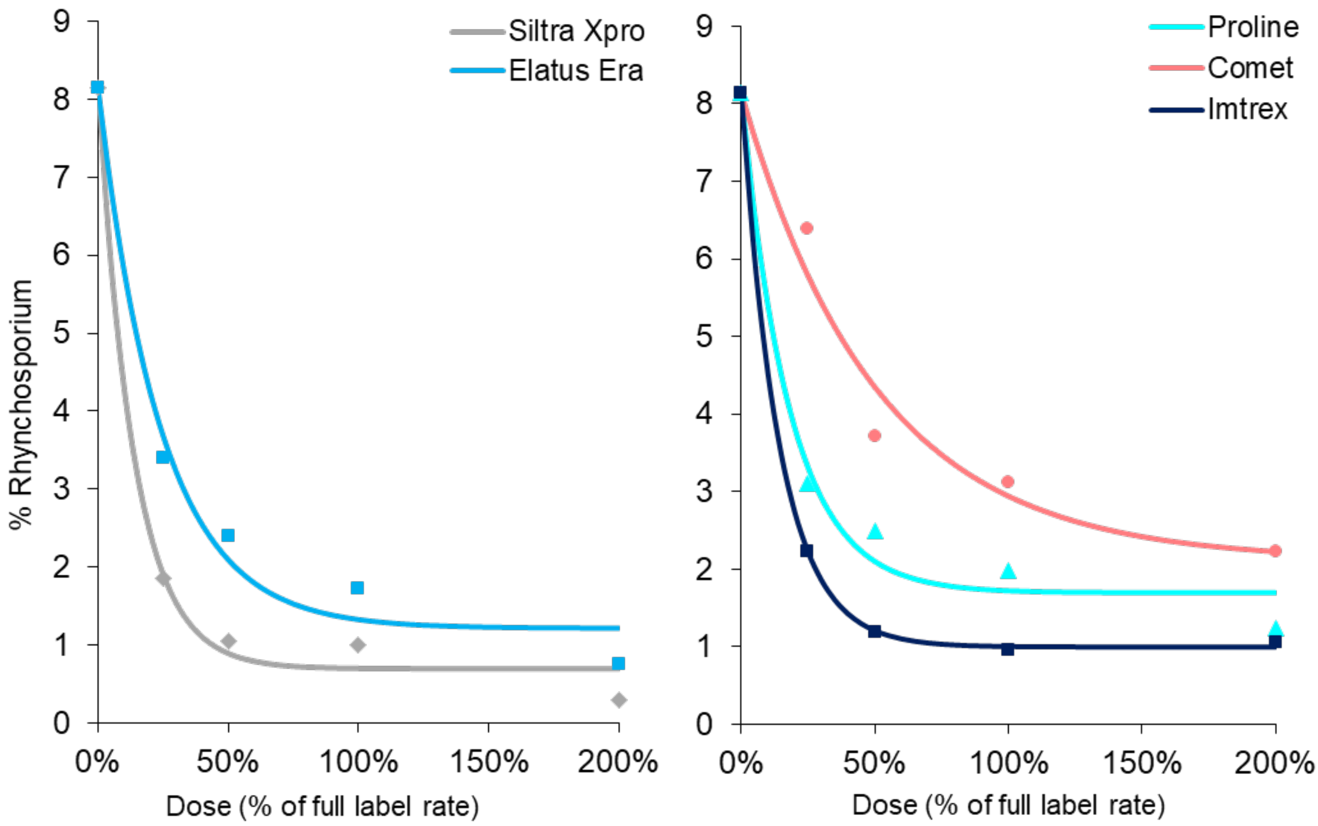

Figure 44: Fungicide dose-response curves for protectant activity against rhynchosporium in 2018 (mean of three trials)

Yield

Yield responses based on a single spray timing will not necessarily reflect the yield responses that would be seen in commercial practice where a more comprehensive strategy is employed. However, yield response data can support disease control information on products and can identify effects on yield that may not be attributable to disease control alone.

In 2015 (Figure 45), Siltra Xpro produced the largest yield response of 1.34 t/ha at full dose rate. The other mixed treatments, Priaxor and Adexar, performed more similarly to Proline and Imtrex, producing yield responses ranging from 0.82 to 1.02 t/ha. Comet, Vertisan and Zulu generated the weakest yield responses, consistent with the poor disease control observed.

Yield responses were smaller in 2016, ranging from 0.28 t/ha (Vertisan) to 0.83 t/ha (Priaxor) at 100% dose rate. All three mixture treatments, Siltra Xpro, Elatus Era and Priaxor performed better than the straight SDHIs, straight azole or strobilurin products (Figure 46).

In 2017, as in other years, the SDHI mixtures produced the largest yield responses of 0.66 to 0.75 t/ha, performing slightly better than Proline and Imtrex (0.56 and 0.50 t/ha) (Figure 47). Reflective of the disease control observed, Proline, Imtrex and Priaxor produced steep dose response curves. As in 2016, Comet and Vertisan performed poorest, producing yield responses of 0.22 to 0.28 t/ha.

Figure 48 shows the yield responses from 2018 treatments. Imtrex performed poorly at all doses, showing only a 0.21 t/ha yield response, in contrast to the strong disease control provided. Comet performed similarly to Imtrex, however was outperformed by Elatus Era, which showed a lower dose response. Proline and Siltra Xpro displayed the greatest yield responses of 0.57 and 0.59 t/ha respectively.

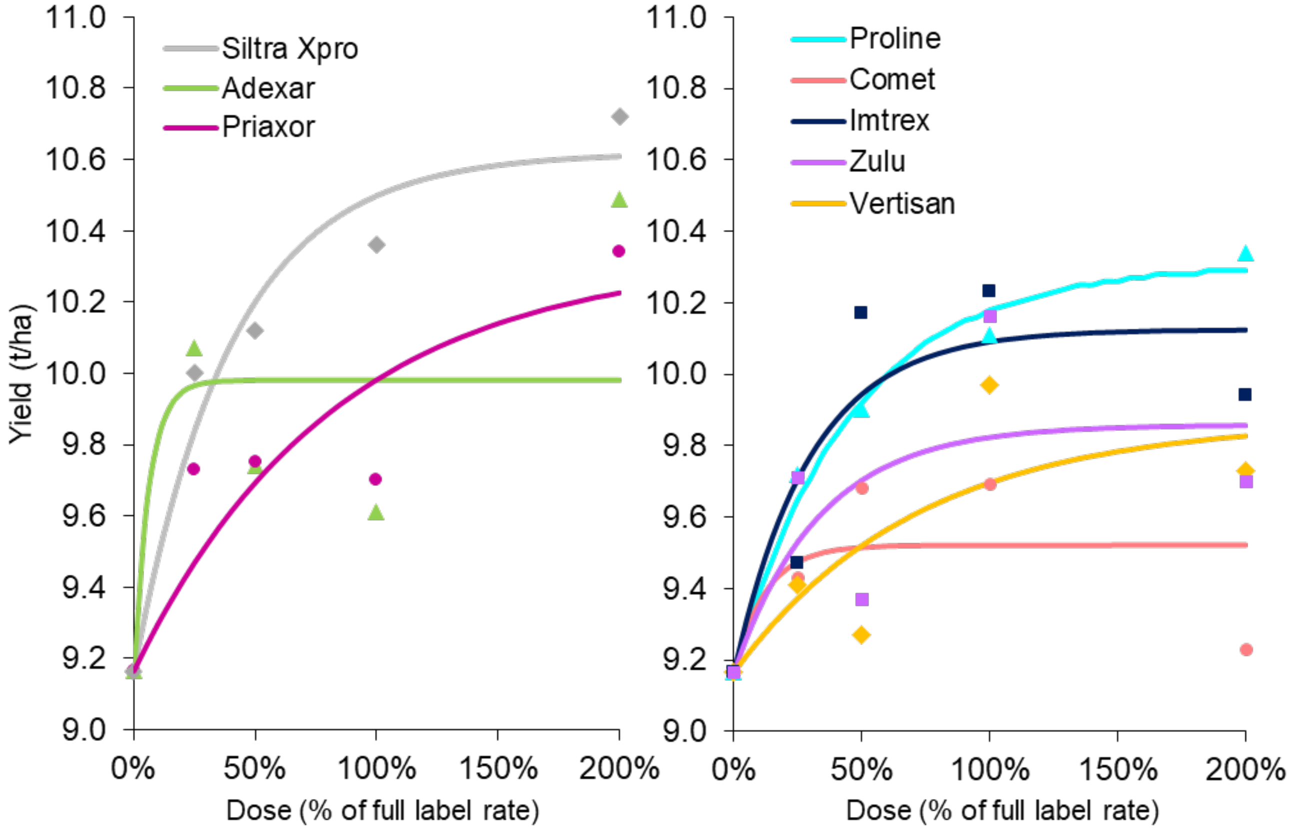

Figure 45: Fungicide dose-response curves for yield in rhynchosporium trials in 2015 (mean of three trials)

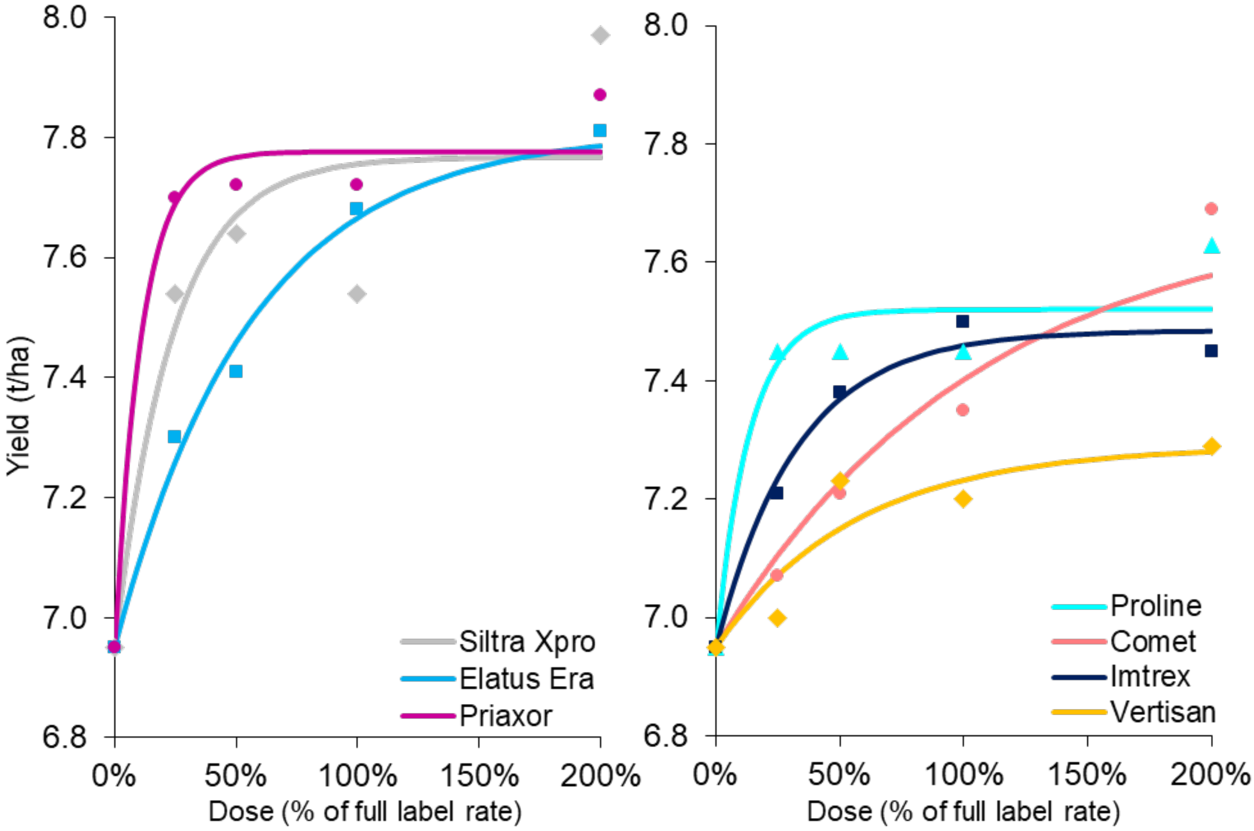

Figure 46: Fungicide dose-response curves for yield in rhynchosporium trials in 2016 (mean of three trials)

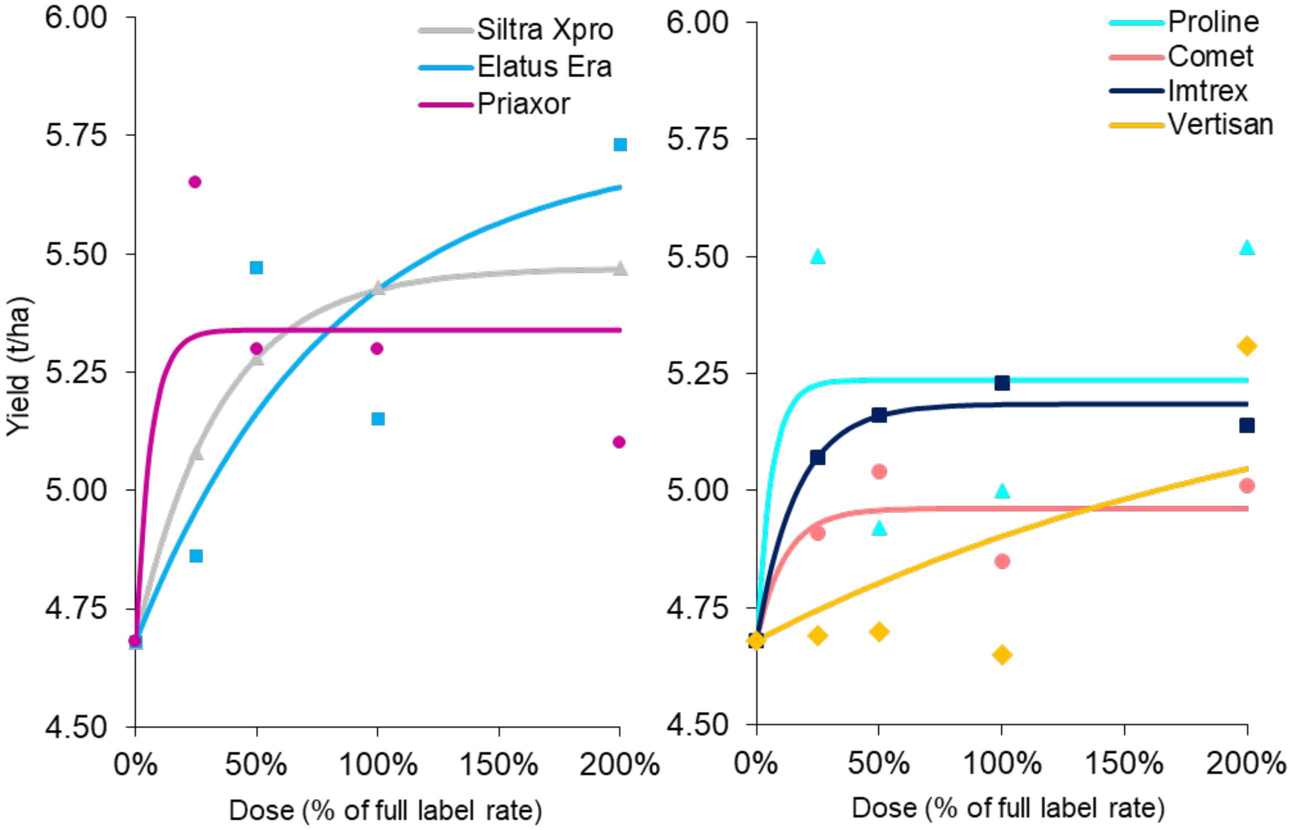

Figure 47: Fungicide dose-response curves for yield in rhynchosporium trials in 2017 (mean of three trials)

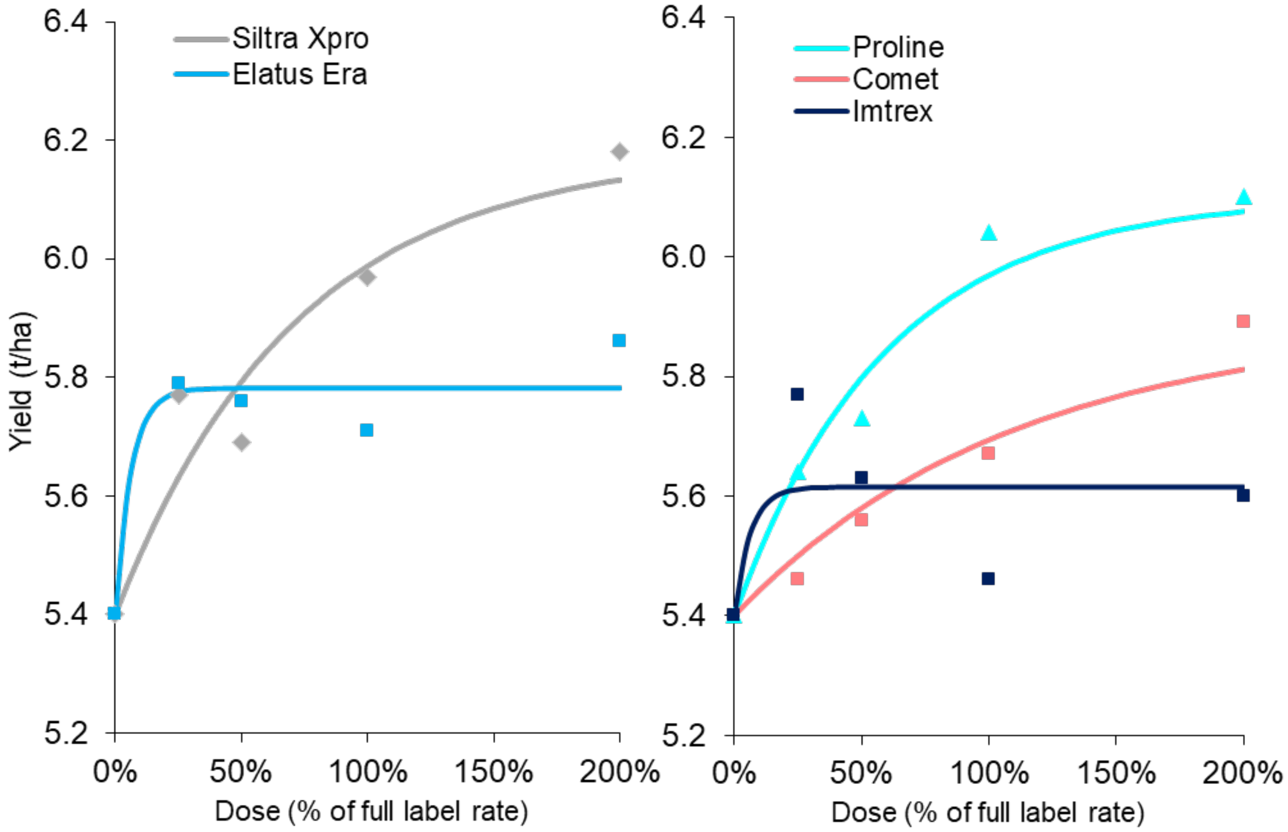

Figure 48: Fungicide dose-response curves for yield in rhynchosporium trials in 2018 (mean of three trials)

Summary

Yield responses broadly match disease control across all four years. The SDHI-azole mixtures, Siltra Xpro and Elatus Era and strobilurin-azole mixture, Priaxor, consistently controlled disease most effectively, generating the greatest yield responses. Of the straight treatments, Proline and Imtrex performed better than Comet and Vertisan in all years.

4.2.2. Net blotch

Disease control

Disease levels in 2015 were relatively low, with the untreated only showing 6.75% net blotch. Of the mixture treatments, Priaxor and Siltra Xpro displayed the highest levels of disease control, but no better than would be expected from the performance of their component parts: Comet (pyraclostrobin) and Proline (prothioconazole). Imtrex, Zulu, Vertisan and Kayak controlled disease to a similar degree, but less effectively than the other treatments (Figure 49).

In 2016, net blotch levels were higher (Figure 50) than in 2015, however as seen in 2015, Proline and Priaxor showed comparable activity, whilst Elatus Era and Siltra Xpro were slightly more effective. The straight SDHIs, Imtrex and Vertisan displayed less activity than the other treatments, with equivalent disease control to each other. In comparison to 2015, the efficacy of Comet was lower.

Low disease pressure was observed at the trial sites in 2017 and all treatments reduced net blotch levels (Figure 51). The straight SDHIs demonstrated least disease control. Elatus Era and Siltra Xpro showed better activity in comparison to Proline, suggesting that the addition of a mixture partner to prothioconazole improved activity.

Only one trial site provided net blotch data in 2018, site 25 at High Mowthorpe, as no disease was present at site 26 (Fakenham). The treatments containing prothioconazole, Elatus Era, Proline and Siltra Xpro displayed the most effective disease control, consistent with data from previous years. The efficacies of Comet and Imtrex were comparable, whereas Kayak performed least effectively (Figure 52).

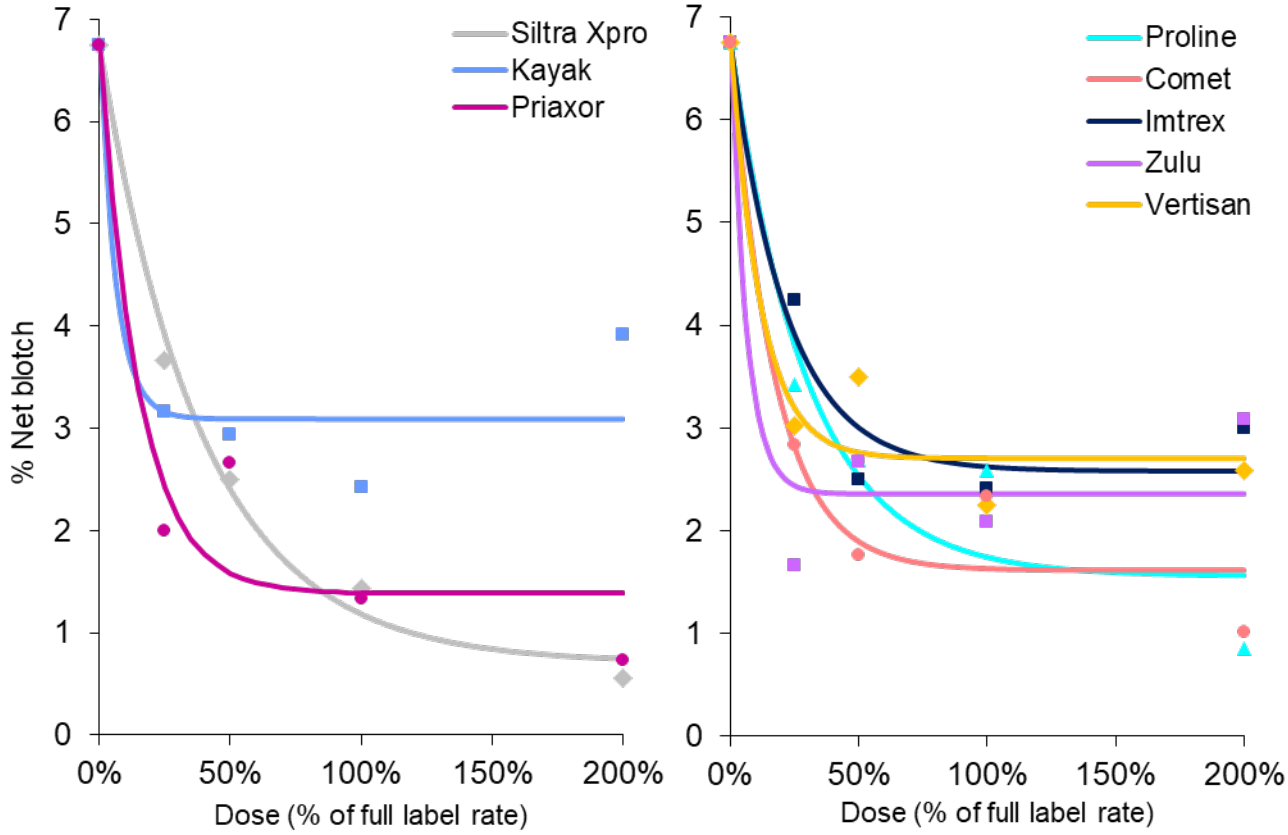

Figure 49: Fungicide dose-response curves for net blotch control in 2015 (mean of two trials)

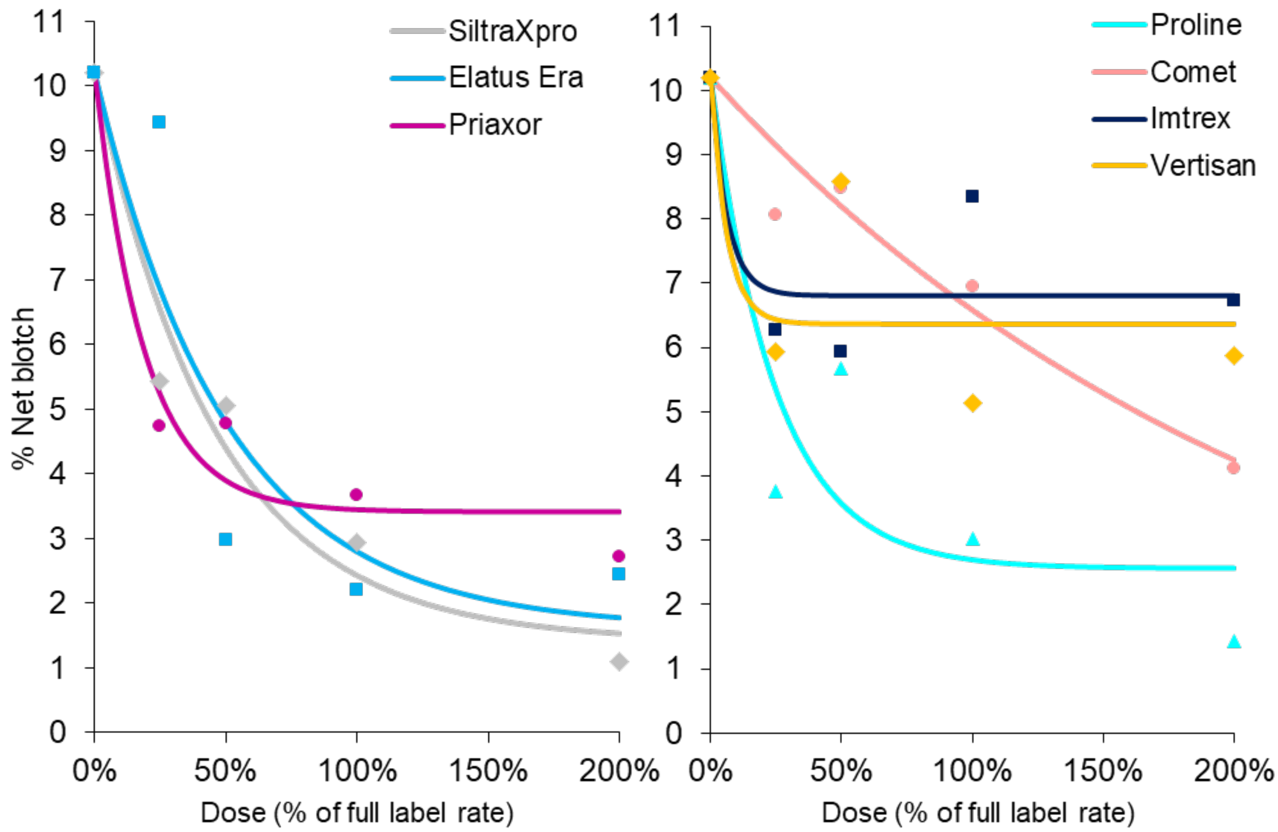

Figure 50: Fungicide dose-response curves for net blotch control in 2016 (mean of two trials)

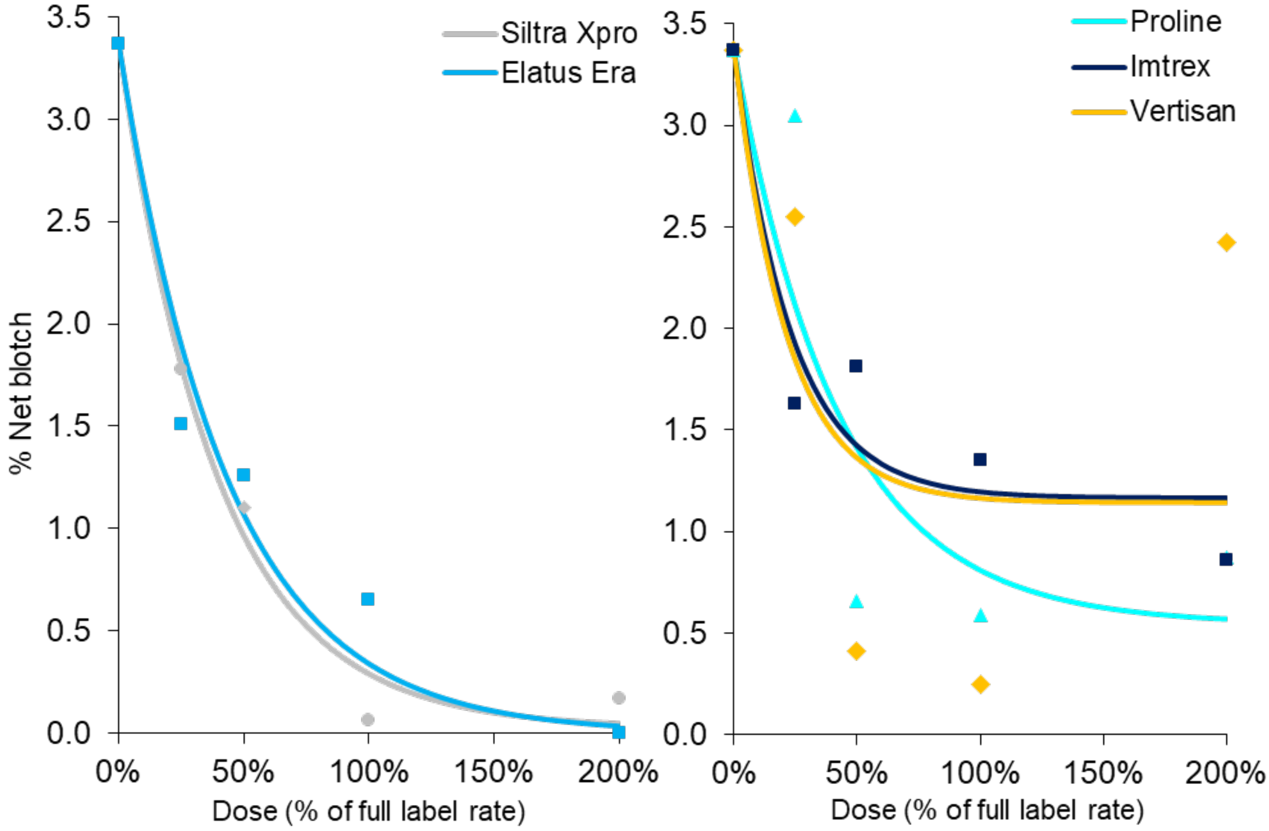

Figure 51: Fungicide dose-response curves for net blotch control in 2017 (mean of two trials)

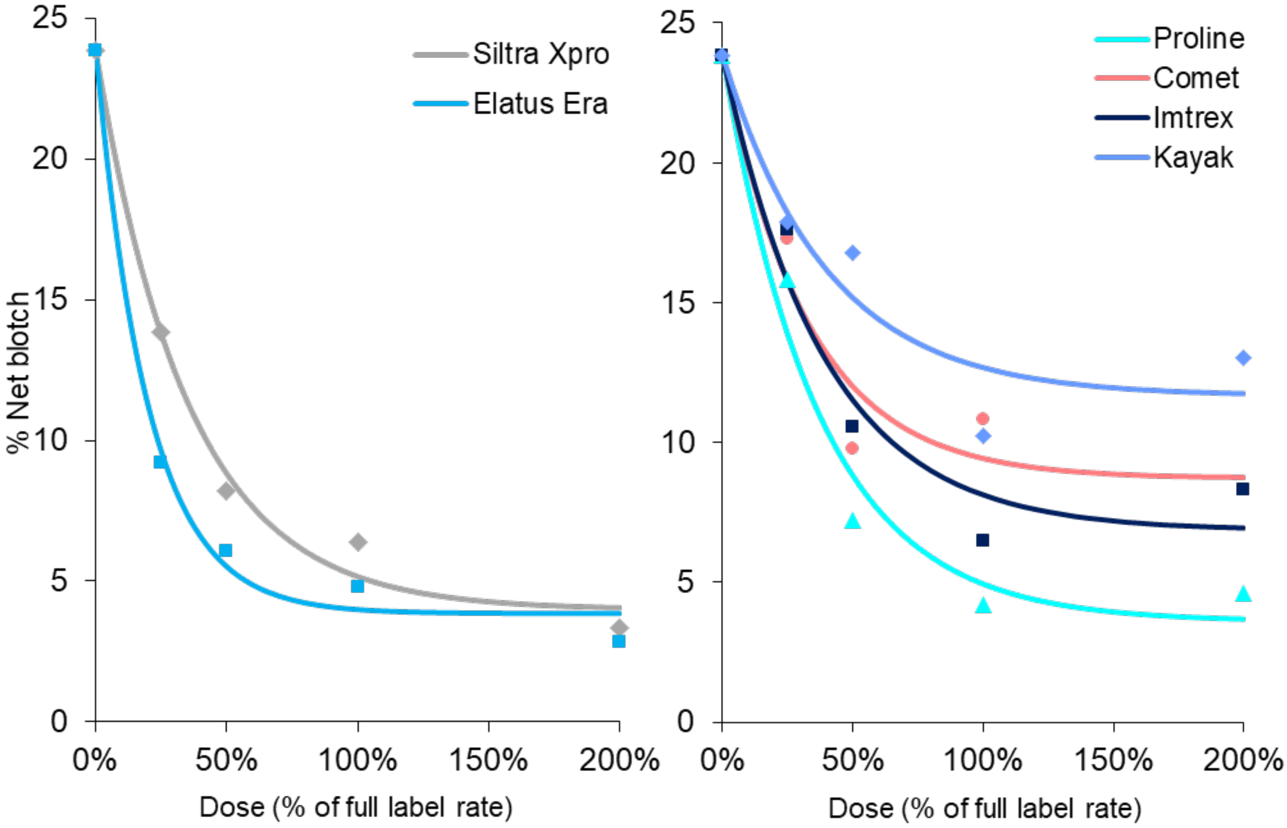

Figure 52: Fungicide dose-response curves for net blotch control in 2018 (site 25)

Yield

Commercial practice on barley typically involves two fungicide applications therefore these yield responses, assessed after a single spray timing, may not reflect yield responses that will be seen in commercial practice. However, yield response data can support information on disease control provided by each product and can identify effects on yield that may not be attributable to disease control alone.

In 2015, Siltra Xpro produced the greatest yield response (0.63 t/ha), followed by Imtrex and Proline (Figure 53). Priaxor, Vertisan and Zulu showed similar yield responses to each other. Despite showing equivalent disease control, Priaxor (fluxapyroxad and pyraclostrobin) showed a yield benefit over Comet (straight pyraclostrobin). Kayak produced the smallest yield response of 0.15 t/ha, consistent with the poor disease control observed.

In 2016, sites 11 (High Mowthorpe) and 12 (Fakenham) showed Proline (straight azole) to have a yield response of 0.45 t/ha, equivalent to the SDHI-azole mixtures containing prothioconazole: Elatus Era (0.42 t/ha) and Siltra Xpro (0.53 t/ha). Elatus Era showed a steeper dose-response gradient. Priaxor and Comet (0.38 t/ha and 0.29 t/ha) were more effective than the straight SDHIs, Vertisan and Imtrex. Figure 54 shows this and although the trends are consistent with the observable disease control, the yield responses are highly variable between each dose and should be treated with caution.

Treatments in 2017 typically generated large yield responses, with Vertisan producing the smallest yield response of 0.43 t/ha. As demonstrated in Figure 51, the treatments containing prothioconazole (Proline, Elatus Era and Siltra Xpro) demonstrated equivalent disease control at all doses and this was reflected in the yield responses (Figure 55). Although Imtrex showed similar disease control to Vertisan at all doses, Imtrex generated the greatest yield response (0.76 t/ha).

At High Mowthorpe (site 25) in 2018, Siltra Xpro generated the highest yield responses, closely followed by Elatus Era and Proline (all containing prothioconazole), as is consistent with the disease control observed. Comet, Kayak and Imtrex performed similarly (Figure 56).

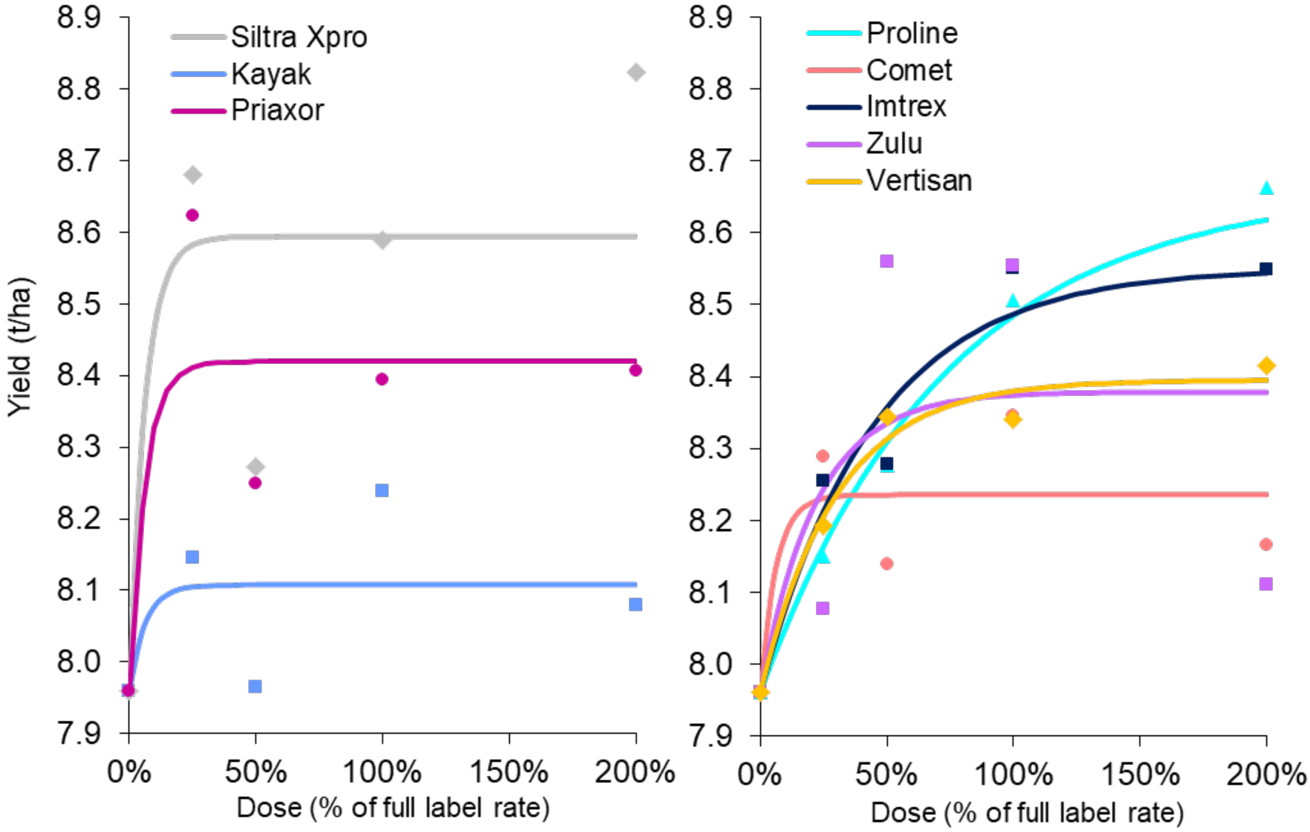

Figure 53: Fungicide dose-response curves for yield in net blotch trials in 2015 (mean of two trials)

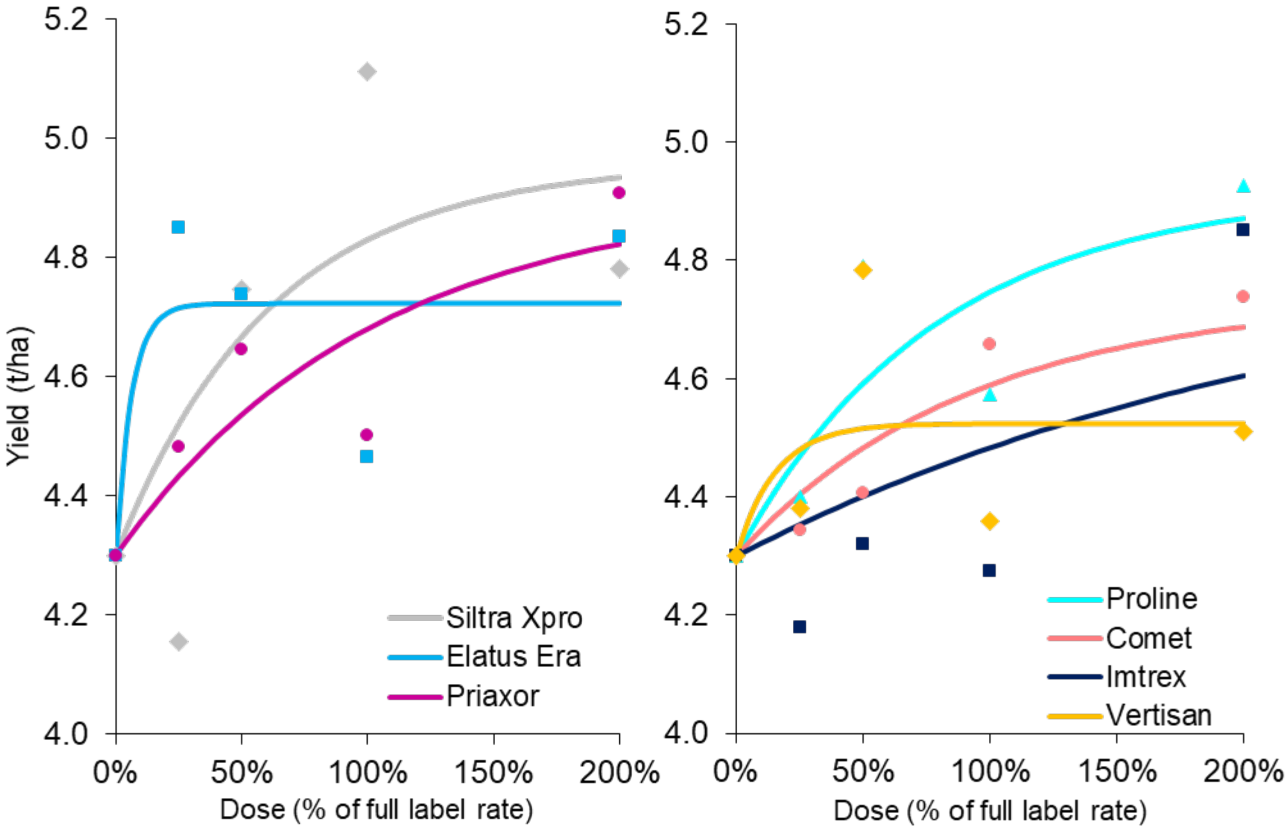

Figure 54: Fungicide dose-response curves for yield in net blotch trials in 2016 (mean of two trials)

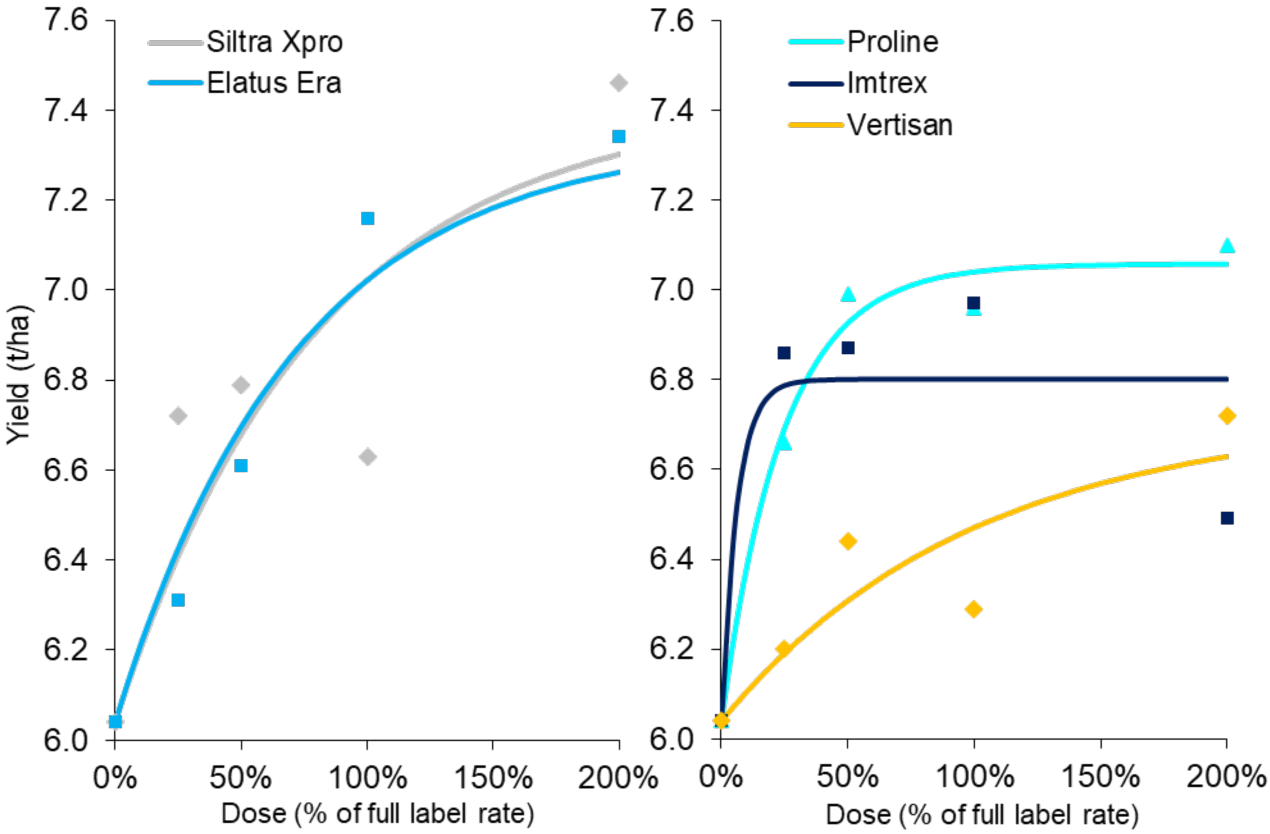

Figure 55: Fungicide dose-response curves for yield in net blotch trials in 2017 (mean of two trials)

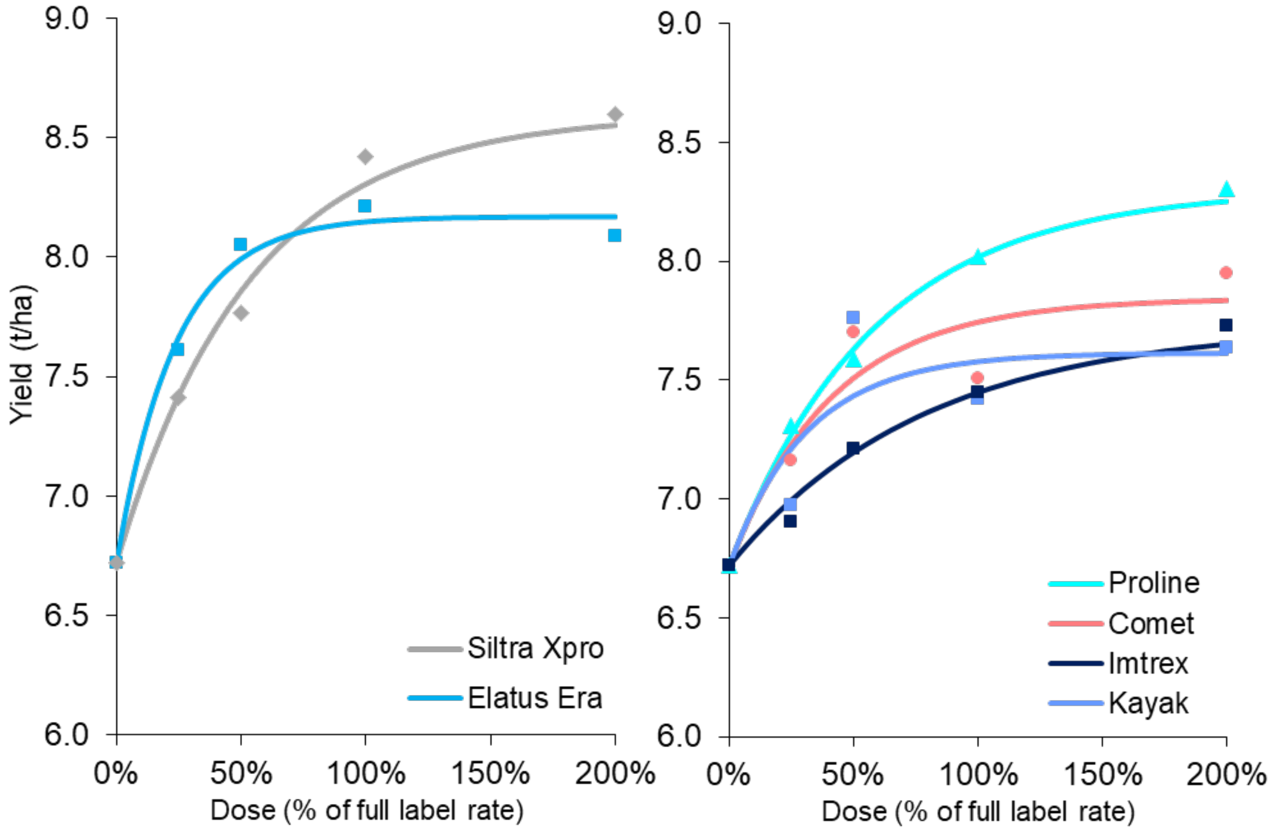

Figure 56: Fungicide dose-response curves for yield in net blotch trials in 2018 (High Mowthorpe, site 25)

Summary

Across the years, the mixed treatments (SDHI-azoles or strobilurin-SDHI) displayed greater activity than the straight components, with Siltra Xpro, Elatus Era and Proline (all containing prothioconazole) and Priaxor consistently outperforming the straight SDHIs. The yield data produced across the range of doses for some treatments were highly variable and as such, values estimated from the dose-response curves should be treated with caution.

4.2.3. Powdery mildew

Disease control

No powdery mildew was observed at the trial site in Midlothian in 2015 (site 2).

Site 9, Midlothian (2016) was designed to target rhynchosporium but differences between treatments on the control of mildew were observed and recorded. The site showed 6.4% powdery mildew present in the untreated (Figure 57). Elatus Era, Proline and Siltra Xpro showed the greatest levels of disease control, suggesting a high level of activity provided by prothioconazole. Vertisan displayed more effective disease control than Comet, which showed the lowest level of activity of the treatments tested. Imtrex and Priaxor, both containing fluxapyroxad, obtained similar levels of control, performing more effectively than Vertisan but displaying less control than Proline and Siltra Xpro.

In 2017, disease pressure was higher, with the untreated control showing 36.4% disease (Figure 58). Good disease control was provided by Proline and Cyflamid (cyflufenamid), with activity stronger than, or equal to Siltra Xpro and Elatus Era (SDHI-azole mixtures). Imtrex and Talius (proquinazid), showed lower levels of activity, although provided more control than Vertisan.

In 2018, comparative efficacy of Cyflamid, Elatus Era and Proline was the same as seen in 2017, with Imtrex performing relatively poorly compared to other treatments. Talius (a specific mildewicide) showed stronger activity in 2018, with control equal to Cyflamid, Elatus Era and Proline (Figure 59).

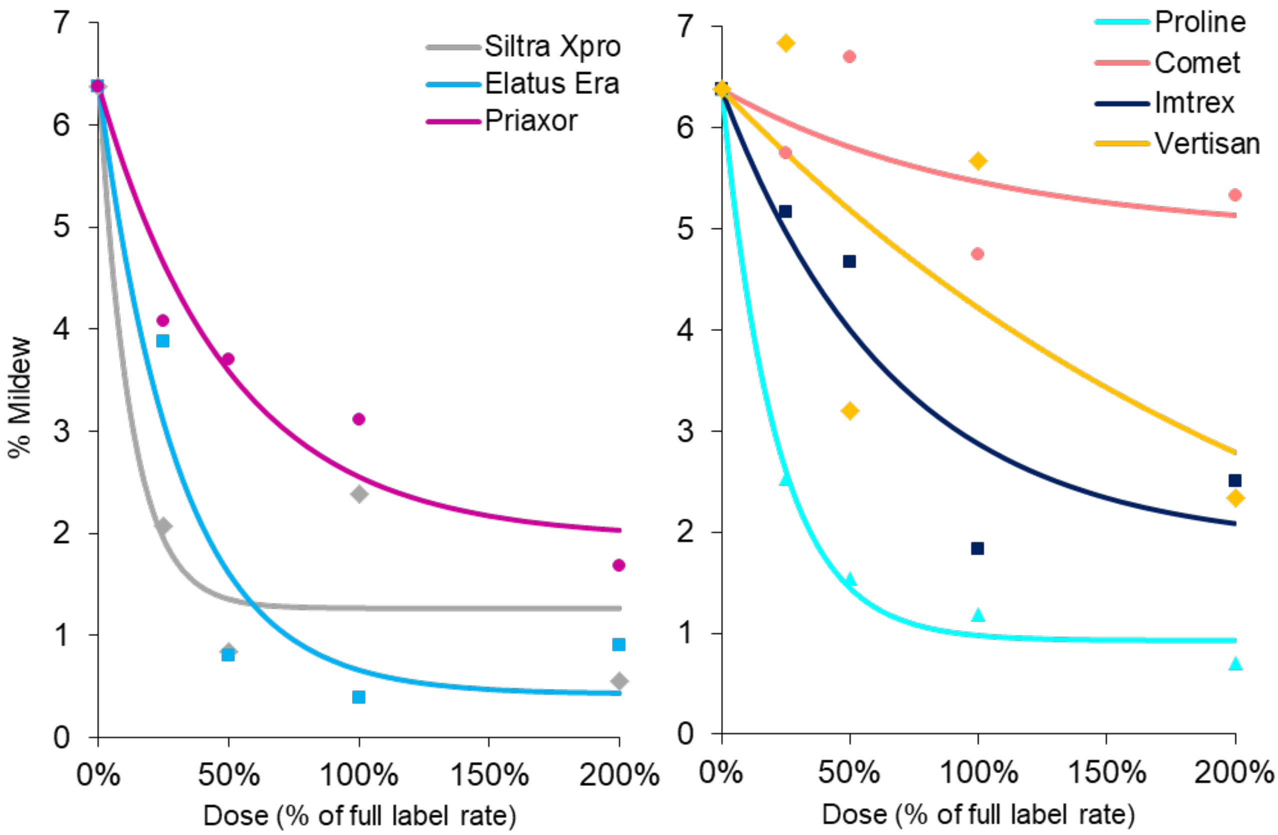

Figure 57: Fungicide dose-response curves for powdery mildew control in 2016 (Midlothian, site 9)

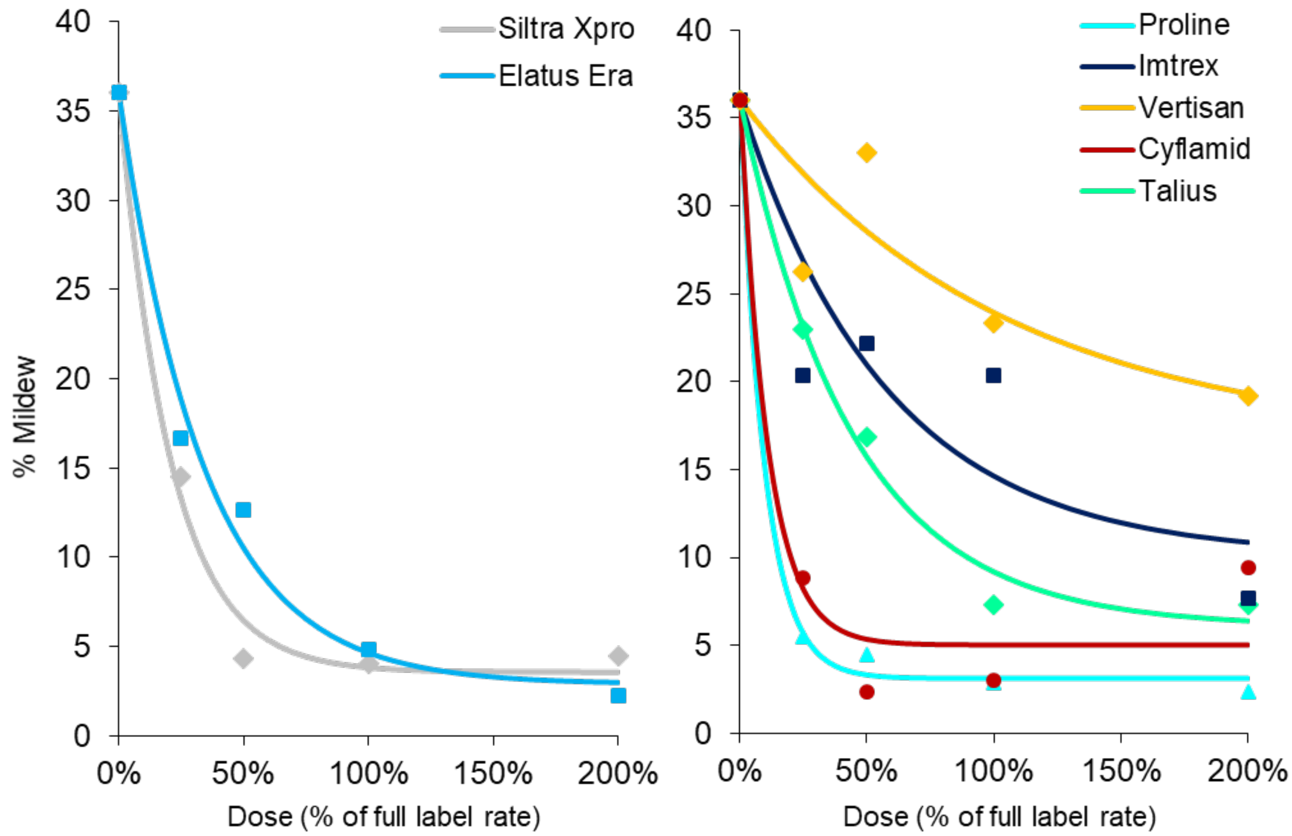

Figure 58: Fungicide dose-response curves for powdery mildew control in 2017 (Midlothian, site 16)

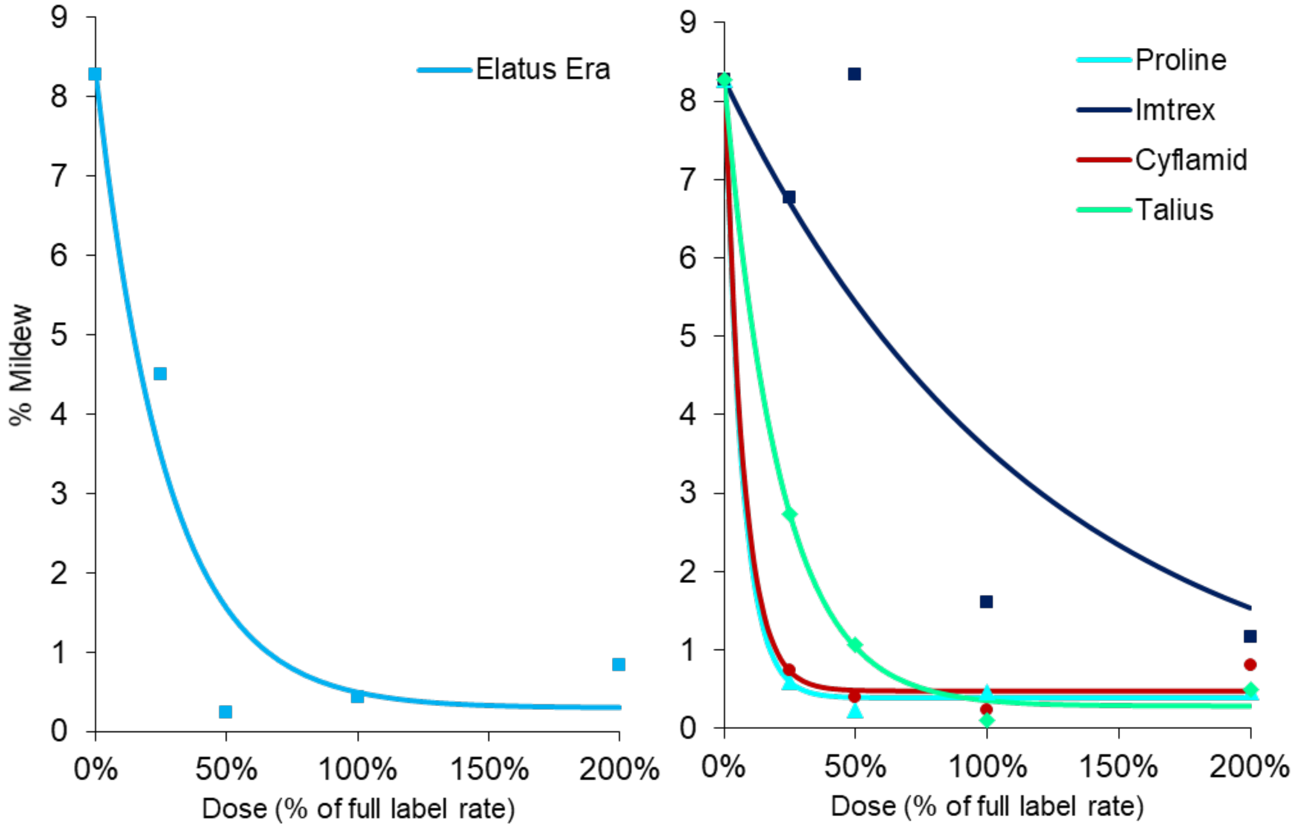

Figure 59: Fungicide dose-response curves for powdery mildew control in 2018 (Midlothian, site 23)

Yield

Although the yield responses were assessed after a single spray timing and so may not reflect those seen in commercial practice, the data obtained can support disease control information for different products.

Due to the absence of powdery mildew at the trial site in 2015, the yield responses produced by different treatments are not reported here. Yield responses in 2016 largely reflected the levels of disease control produced by the different treatments (Figure 60). Priaxor generated a greater yield response (0.96 t/ha) than anticipated from the level of disease control, whilst Siltra Xpro produced a lower yield response relative to the disease control observed (0.62 t/ha). Imtrex produced a yield response of 0.79 t/ha, similar to Elatus Era. Comet showed the smallest improvement in yield out of all the treatments.

Although the disease control observed in 2017 was strong, the relative yield responses produced by the treatments are less consistent. The data are variable and fit the curves poorly (Figure 61), making it is difficult to draw conclusions regarding the relative efficacy of the different treatments. Elatus Era, Siltra Xpro and Imtrex (0.62 to 0.65 t/ha) generated slightly lower yield responses compared to

Proline (0.76 t/ha) but higher than Cyflamid (0.46 t/ha). Although Talius appeared to control disease well, a yield response of only 0.21t/ha was obtained, equivalent to the 0.19 t/ha produced by Vertisan.

Figure 62 displays the 2018 yield response data from site 23 (Midlothian). Elatus Era and Imtrex performed as well as the mildewicides Cyflamid and Talius, whilst Proline showed the largest yield improvement relative to the untreated (0.76 t/ha).

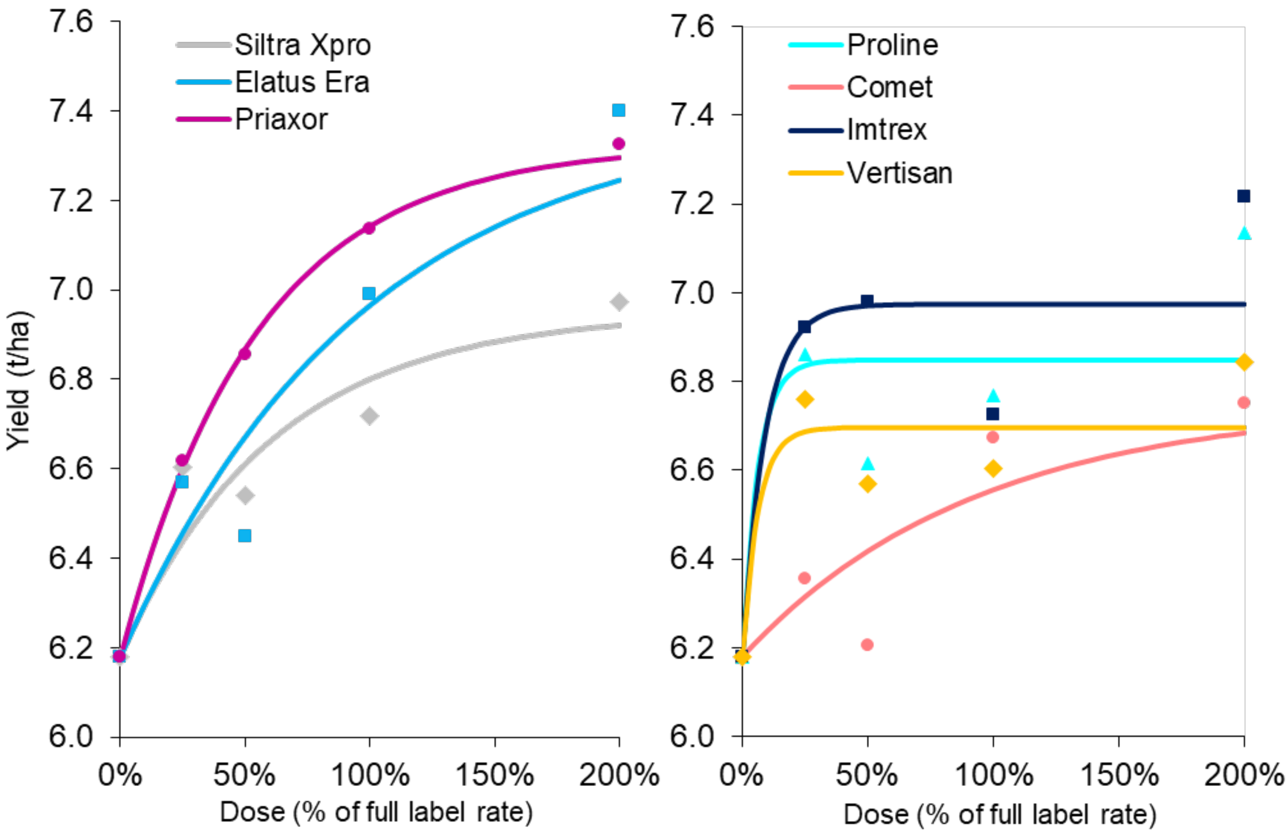

Figure 60: Fungicide dose-response curves for yield in powdery mildew trials in 2016 (Midlothian, site 9)

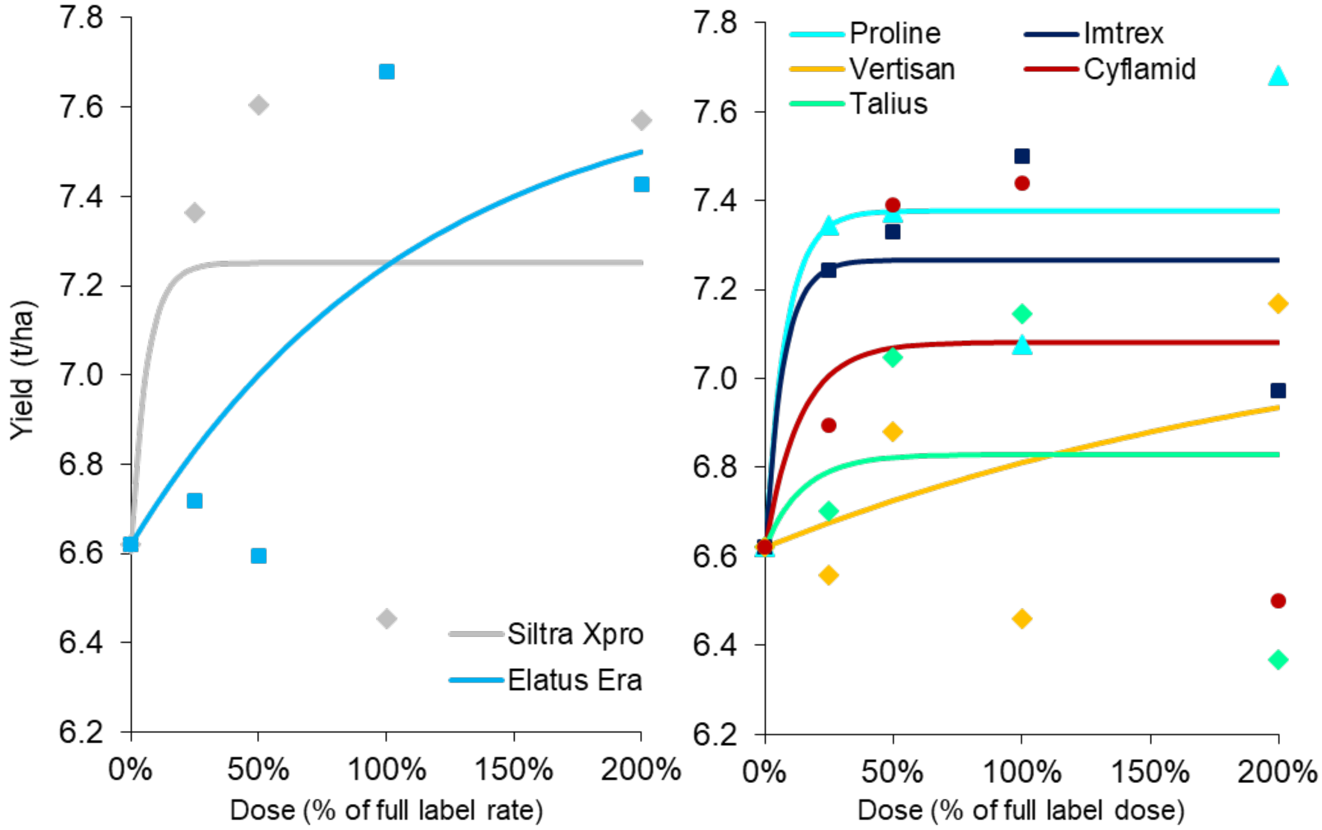

Figure 61: Fungicide dose-response curves for yield in powdery mildew trials in 2017 (Midlothian, site 16)

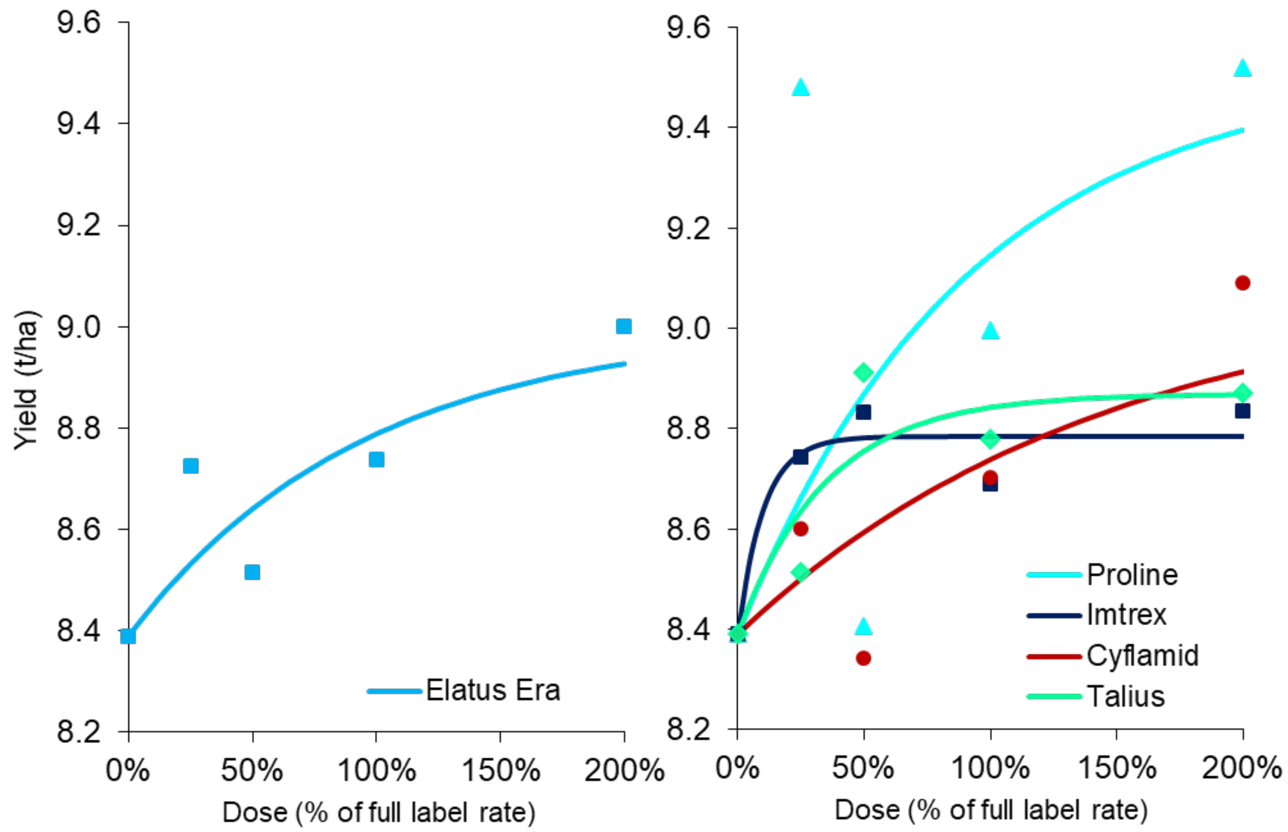

Figure 62: Fungicide dose-response curves for yield in powdery mildew trials in 2018 (Midlothian, site 23)

Summary

From the results demonstrated in Figure 57 toFigure 62, it appears that two compounds are primarily responsible for activity: prothioconazole in Proline, Siltra Xpro and Elatus Era, and fluxapyroxad in Imtrex and Priaxor. The specific mildewicides, Cyflamid and Talius displayed strong disease control, but weaker yield responses in comparison to the other treatments. Only a single site was used to generate data each year and as such, the reliability of the comparisons made could be improved by further replication.

4.2.4. Ramularia

Disease control

In 2015, Treoris showed the strongest levels of activity at all doses, controlling disease more effectively than Bravo (chlorothalonil) suggesting that penthiopyrad (a SDHI) was adding activity to chlorothalonil in Treoris. The SDHI-azole, Siltra Xpro showed equal control to Bravo, whilst Adexar also performed strongly. The straight SDHIs (Imtrex, Vertisan) performed equally to the straight azoles (Proline, Zulu). Dose responses were generally weak for most treatments, with low doses showing similar disease control to full rate application, likely due to the low disease pressure (Figure 63).

No ramularia was observed in 2016 at site 13 (Midlothian).

Disease pressure was low at the ramularia trial sites in 2017 and only 5% disease was seen in the untreated plots (Figure 64). Most of the treatments provided negligible disease control; only Treoris and Bravo (both containing chlorothalonil) showed activity and were similarly effective at full dose rates.

Site 27 (Midlothian) showed no ramularia in 2018.

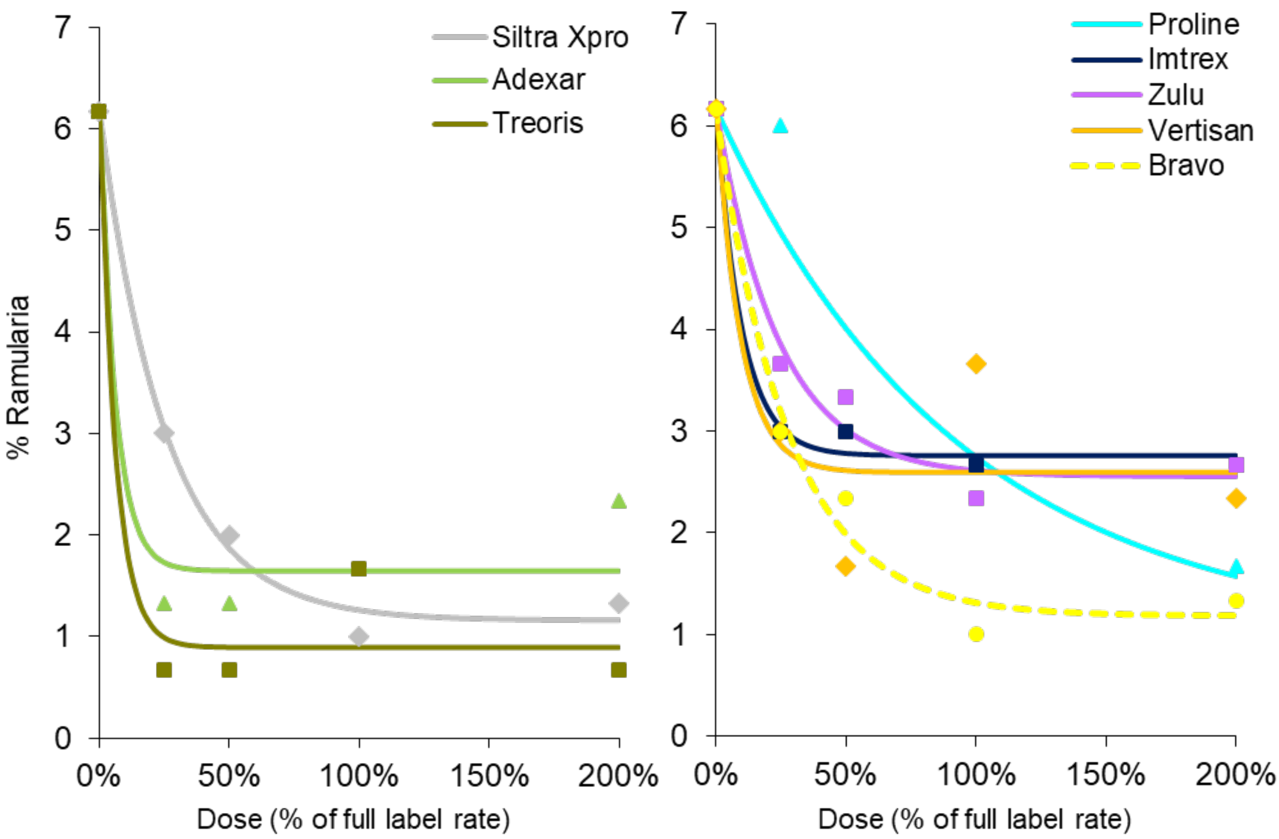

Figure 63: Fungicide dose-response curves for ramularia control in 2015 (Midlothian, site 6)

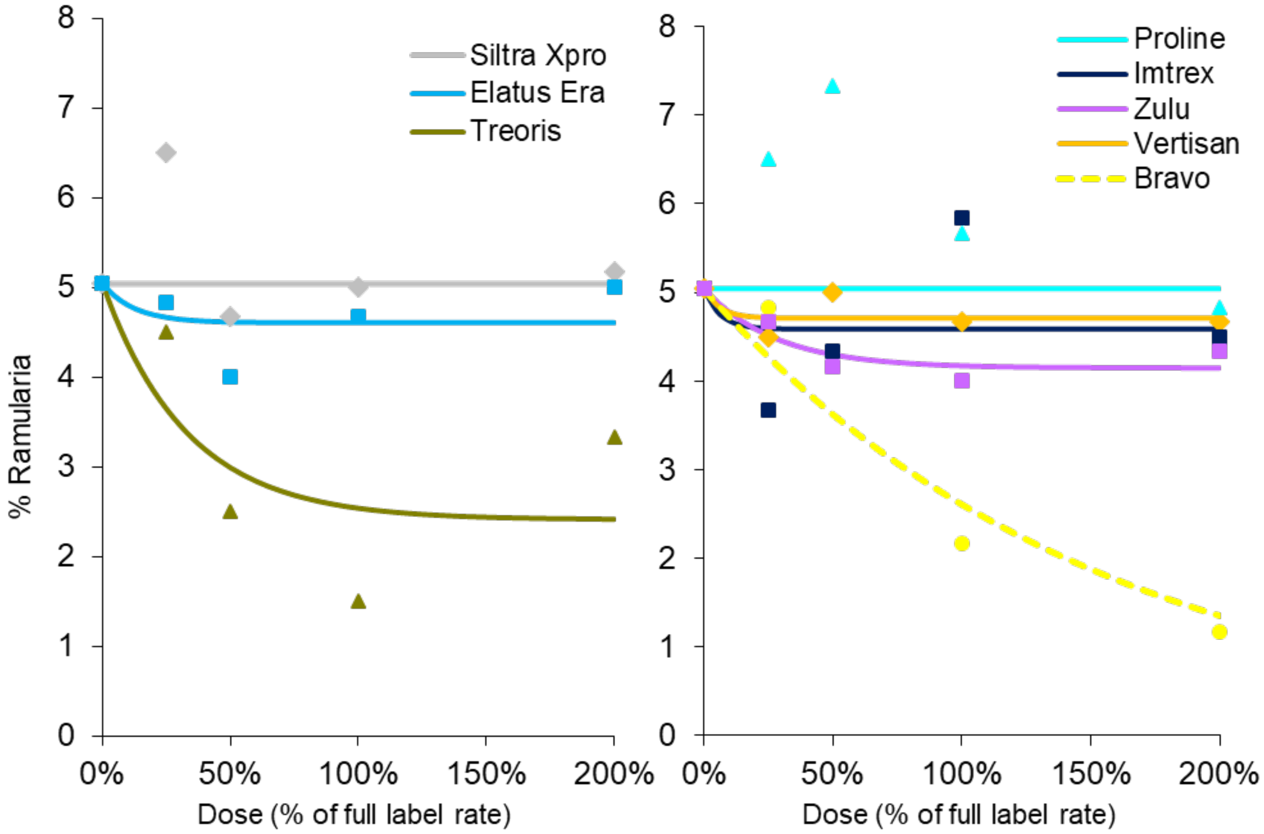

Figure 64: Fungicide dose-response curves for ramularia control in 2017 (Midlothian, site 20)

Yield

Commercial practice typically involves a more comprehensive fungicide application programme therefore these yield responses, assessed after a single spray timing, may not reflect yield responses that will be seen in commercial practice.

All treatments except Zulu produced clear yield responses in 2015, with a maximum response of 1.18 t/ha obtained by Siltra Xpro at 100% dose rate (Figure 65). All other treatments, with the exception of Zulu, produced similar responses of 0.53 to 0.88 t/ha, with Proline, Imtrex and Bravo displaying evidence of steeper dose responses. Treoris showed a low yield response relative to the strong disease control observed.

No ramularia was present at Midlothian (site 13) in 2016.

Although disease control was poor in 2017, all treatments produced a yield response, ranging from Vertisan (0.17 t/ha) to Elatus Era, Treoris, Bravo and Proline (~0.5 t/ha). Siltra Xpro performed poorly in comparison to 2015, perhaps due to the low disease pressure. Poor dose responses were seen across all the treatments except Elatus Era (Figure 66).

Site 27 (Midlothian) showed no ramularia in 2018.

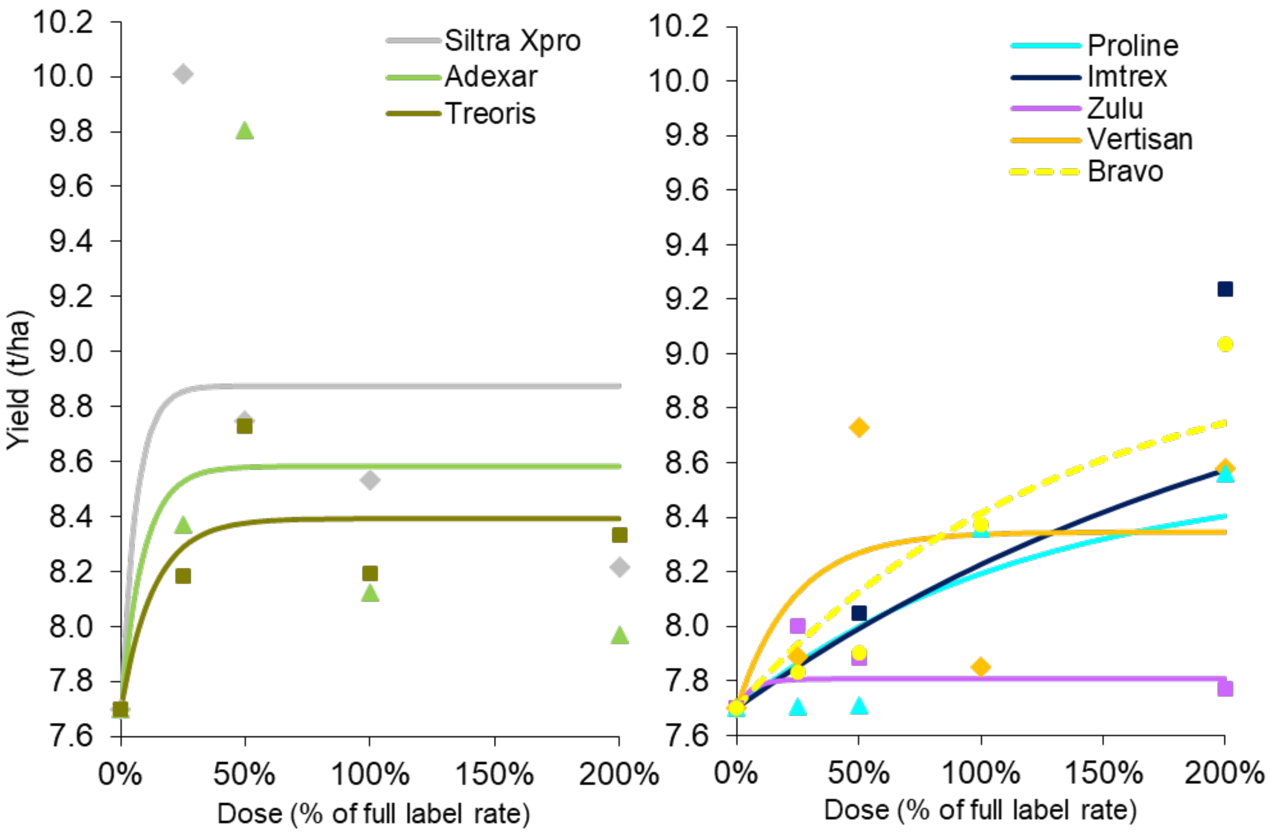

Figure 65: Fungicide dose-response curves for yield in ramularia trials in 2015 (Midlothian, site 6)

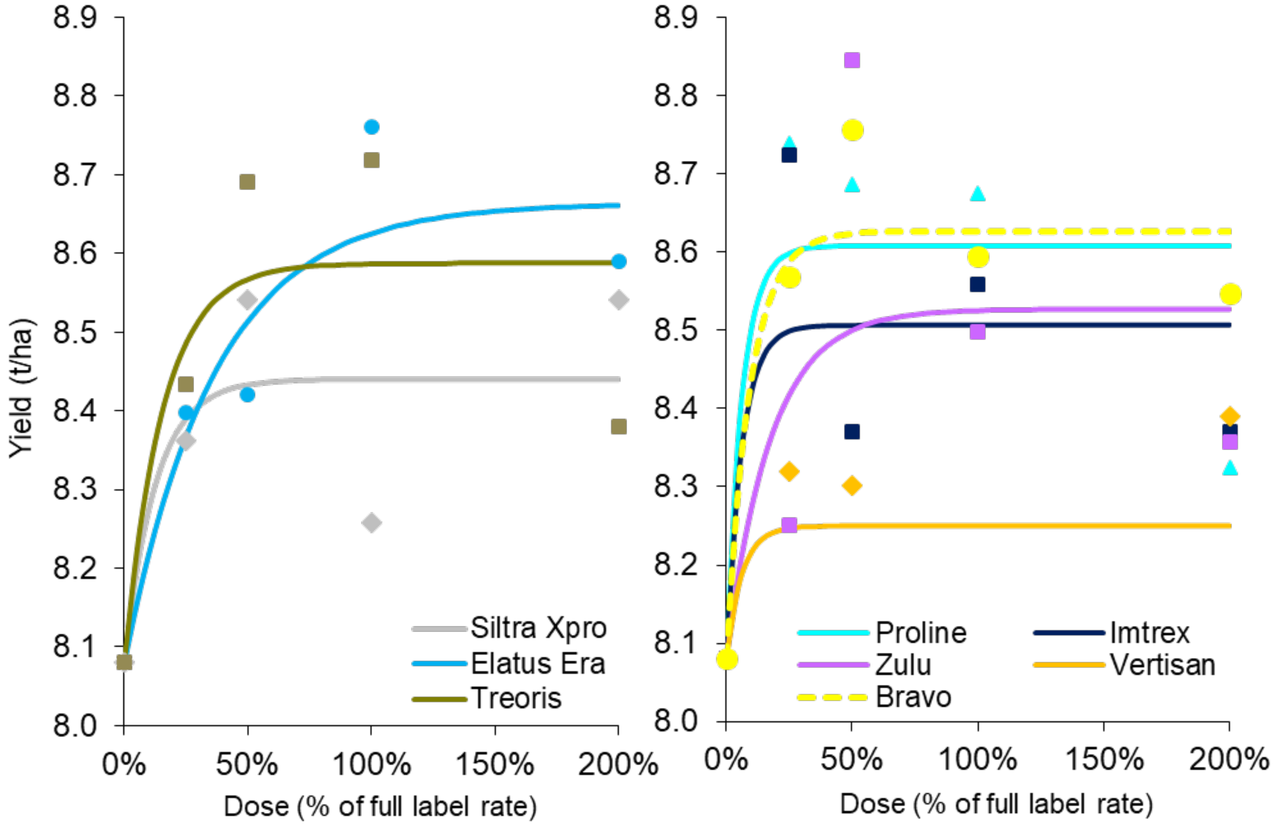

Figure 66: Fungicide dose-response curves for yield in ramularia trials in 2017 (Midlothian, site 20)

Summary

Due to the absence of disease in 2016 and 2018, low disease pressure in 2015 and 2017 and testing at a single site, the data available to determine relative efficacy of fungicides on ramularia is limited. There is some indication that the treatments containing SDHI mixtures (Adexar, Elatus Era, Siltra Xpro, Treoris), and multi-site inhibitors (chlorothalonil in Treoris and Bravo) may control disease more effectively than the straight SDHI or straight azoles, displaying greater levels of activity at lower doses.

4.3. Oilseed Rape

4.3.1. Phoma leaf spot and stem canker

Disease control

Low disease severity was observed at Boxworth (site 3) (index 27 in untreated control) in 2015 and data are not shown. At Terrington (site 4) in 2015, stem canker severity was moderate (index 55 in untreated control). Fifty percent of plants had phoma leaf spot in the untreated control at the 8-leaf stage on 31 October indicating a more curative situation when first fungicides were applied. Second sprays were applied on 9 December (48% incidence; 0.1% leaf area affected). Proline, Refinzar and Pictor all decreased the stem canker index to less than 30 where at least half the recommended label rate was applied. In contrast, Cirkon and Orius 20EW were less effective at decreasing the stem canker index (Figure 67).

Filan was included for the first time in harvest year 2016. Overall, stem canker severity was low at Terrington (index 24 in untreated) and high at Boxworth (index 71 in untreated) prior to harvest in 2016. Low levels of phoma leaf spot were observed at both sites until mid-October. At Terrington, first sprays were applied on 26 October 2015, with 32% of plants showing phoma leaf spot symptoms in the untreated control at the 5-leaf stage. At Boxworth, 28% of plants had phoma leaf spot at the 6-leaf stage on 23 October 2015. Poor weather meant second sprays were delayed at both sites. The second spray at Boxworth was applied on 15 December 2015 at the 10-leaf stage (87% incidence; 1.4% leaf area affected) and at Terrington on 7 December 2015 at the 9-leaf stage (55% incidence; 0.14% leaf area affected). At Terrington, despite low disease pressure, there were differences in the effectiveness of the individual products on stem canker, with Cirkon generally less effective than other products tested. A similar pattern was observed at Boxworth, where disease pressure was higher, with the stem canker index decreased from 71 in untreated to less than 30 by most treatments (Figure 68).

Stem canker severity was moderate at Terrington (index 41 in untreated) and low at Rosemaund (index 11 in untreated) prior to harvest in 2017. The phoma epidemic this year was relatively late therefore cankers developed but there was little impact on yield. Poor weather and late re-infection meant second sprays were delayed at both sites. At Rosemaund, fungicides were applied when 45% of plants had phoma leaf spot at the 6-leaf stage on 27 October 2016 and on 14 February 2016 at the 9-leaf stage (23% incidence; 0.05% leaf area affected). At Terrington, first sprays were applied on 15 November 2016, with 30% of plants having phoma leaf spot symptoms in the untreated control at the 7-leaf stage. The second spray at Terrington was applied on 5 January 2016 at the 9-leaf stage (77% incidence; 0.4% leaf area affected). All products tested, Filan, Proline and Refinzar, performed similarly, with no further decreases in stem canker index beyond application of half the recommended label rate (Figure 69).

Stem canker severity was high at Terrington (index 78 in untreated) and moderate at Rosemaund (index 37 in untreated) prior to harvest in 2018. The phoma epidemic was early and prolonged. Both sites still had almost 100% plants with lesions throughout November and December 2017. At Rosemaund, first sprays were applied on 23 October 2017 at the 6-leaf stage (40% phoma leaf spot incidence, 0.5% leaf area affected) and the second spray on 20 December 2017 at the 12-leaf stage (98% phoma leaf spot incidence; 1.0% leaf area affected). At Terrington, first sprays were applied on 9 October 2017 (60% phoma leaf spot incidence; 0.9% leaf area affected) at the 7-leaf stage. The second spray at Terrington was applied on 21 November 2017 at the 12-leaf stage (100% phoma leaf spot incidence; 2.6% leaf area affected). At Rosemaund, stem canker indices were moderate (index 37) in the untreated controls. Decreases in stem canker severity were observed following fungicide application for all products (Figure 1). The largest decrease was observed for Filan, with Proline and Plover performing similarly. At Terrington, stem canker levels were high (index 78 in the untreated controls). Filan was the most effective, decreasing the stem canker index to 30 whilst Proline and Plover decreased canker indices to between 50 and 60; this was a similar pattern to Rosemaund.

Data derived from 3 experiments conducted in years where the canker index was moderate to severe (index 43 to 71 in untreated: Boxworth 2014, Terrington 2015 and Boxworth 2016) were subjected to a cross site analysis to determine average effects on disease and yield across years. Pictor, Refinzar and Proline reduced disease to comparable levels, whilst Orius 20EW and Cirkon were less effective (Figure 71).

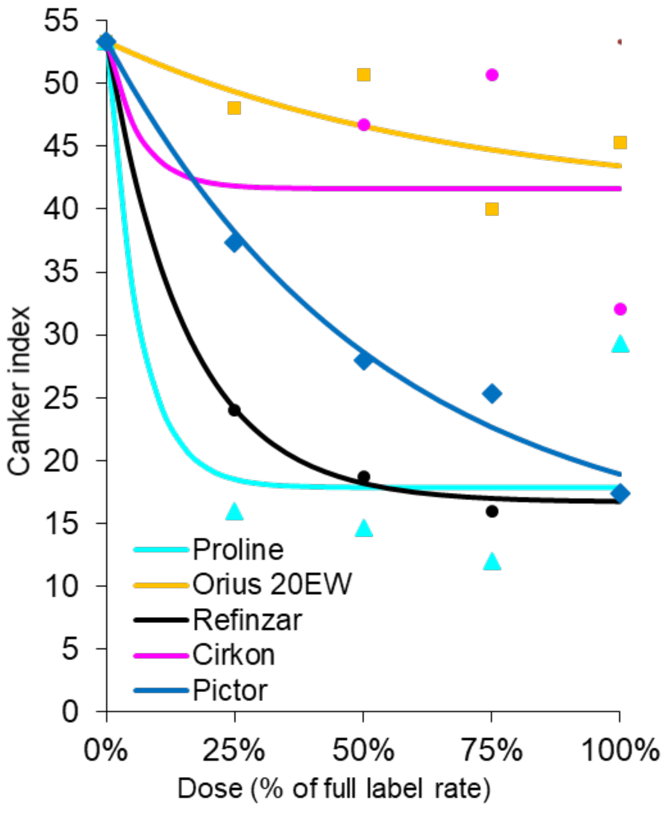

Figure 67: Fungicide dose-response curves for phoma stem canker control at Terrington in 2015 (site 4). Refinzar is no longer available, however, is included for reference.

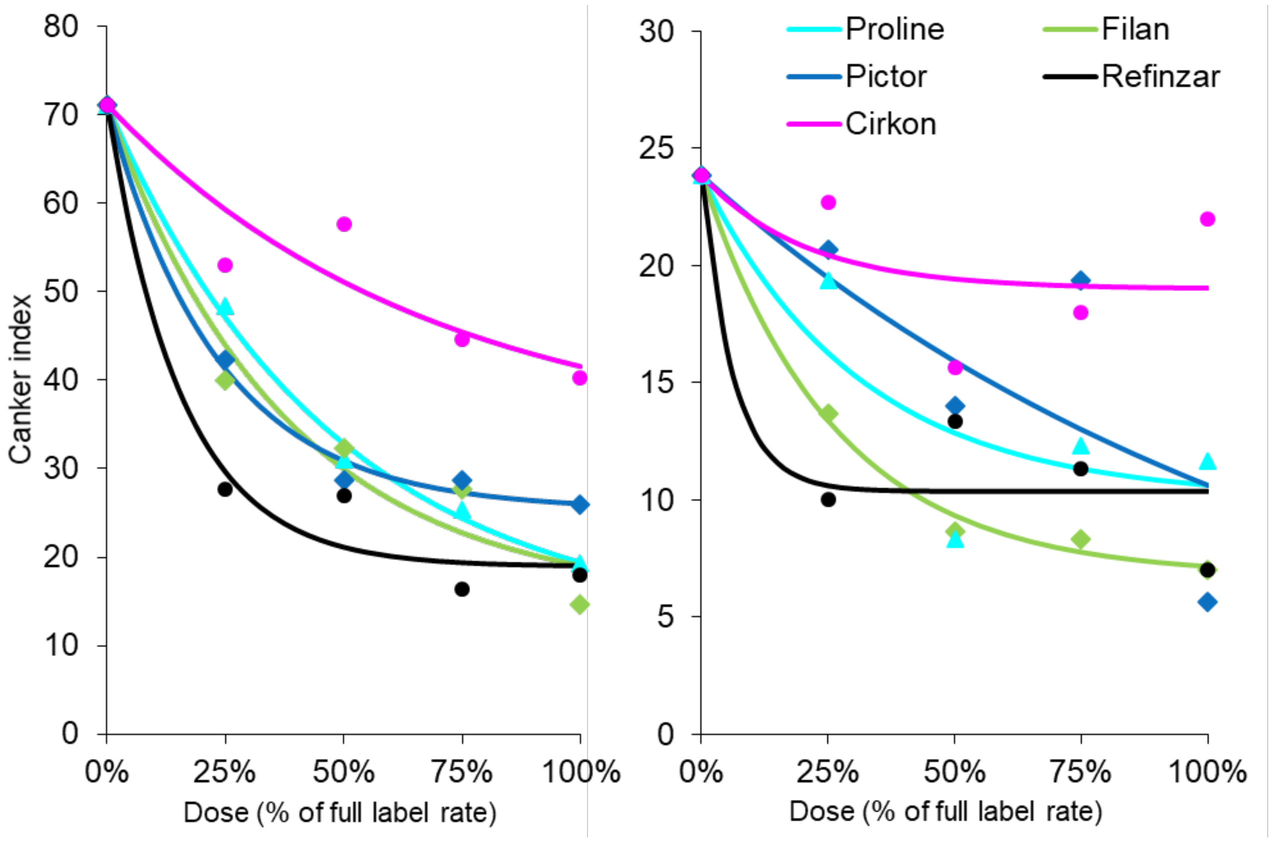

Figure 68: Fungicide dose-response curves for phoma stem canker control in 2016. Left: Boxworth, site 10. Right: Terrington, site 11. Refinzar is no longer available, however, is included for reference. Note that each chart has different axes.

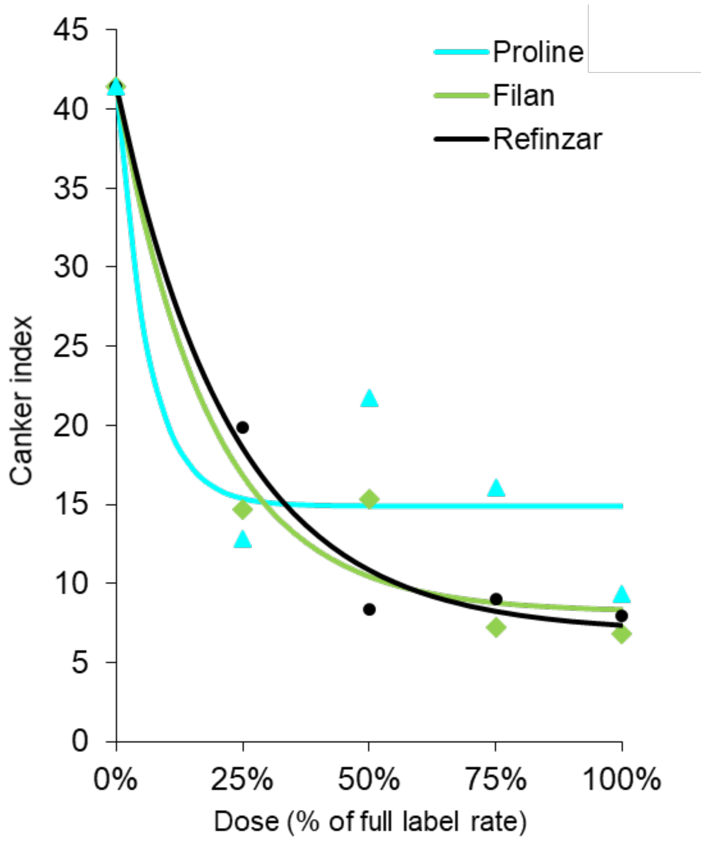

Figure 69: Fungicide dose-response curves for phoma stem canker control in 2017 at Terrington, site 18. Refinzar is no longer available, however, is included for reference.

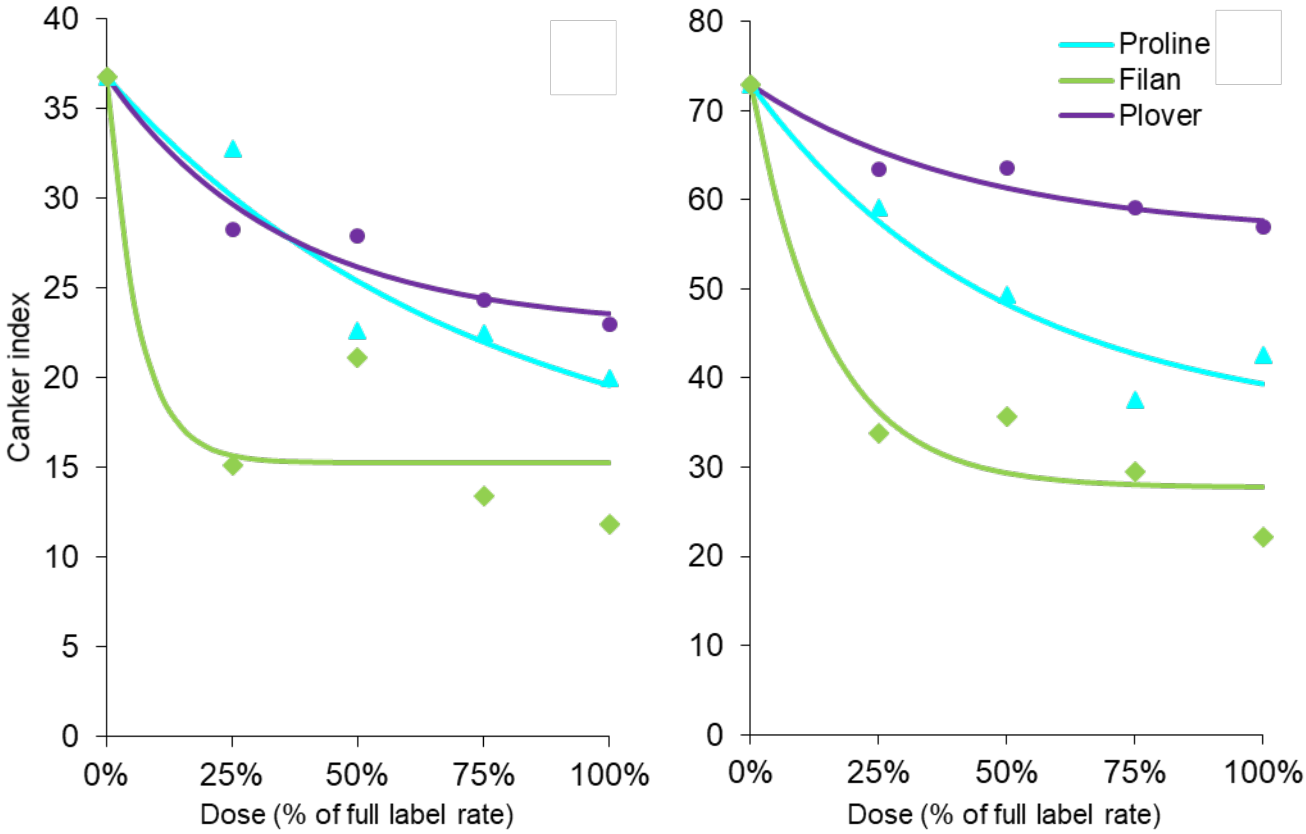

Figure 70: Fungicide dose-response curves for phoma stem canker control in 2018. Left: Rosemaund, site 24, Right: Terrington, site 25. Plover is restricted by a maximum total dose equivalent to a full rate application. Therefore, the 2 spray programmes exceeding 2 x 0.5 rate are above the maximum recommended dose. Note the charts have different axes.

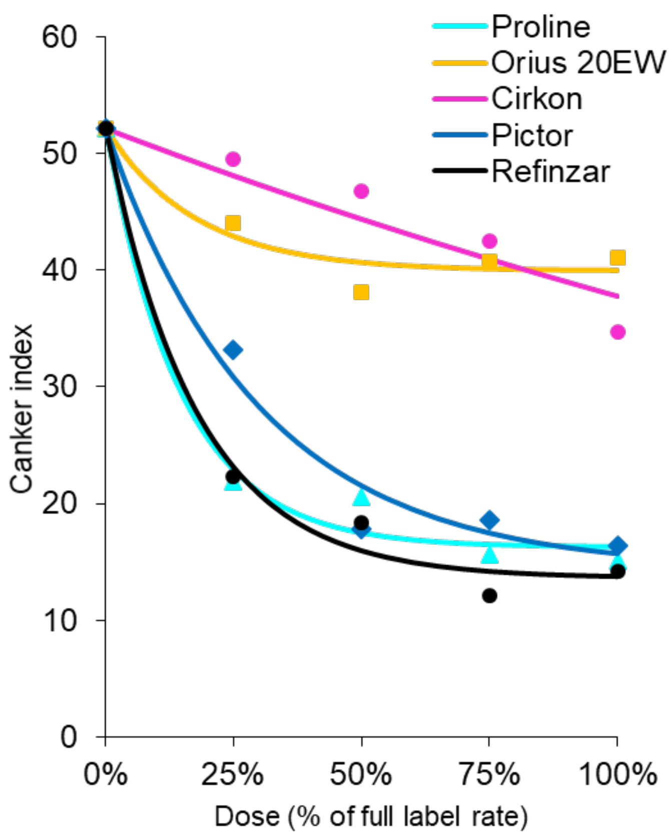

Figure 71: Fungicide dose-response curves for phoma stem canker – cross site analysis using trials with moderate to high canker indices (greater than index 40) in 2014 – 2016.

In 2015 at Boxworth, there were no yield responses to fungicides, therefore data are excluded from this report. Terrington (site 4) was a high yielding site (untreated yield = 4.55 t/ha) and yield responses ranged from 0.21 to 0.54 t/ha. Decreasing stem canker index to at least 45 gave a significant increase in yield for all products relative to the untreated control. Despite appearing less effective against stem canker, Cirkon performed similarly to other products for yield. Yields were lower for Orius 20EW, particularly at the three-quarters and full rates, suggesting that higher doses on small plants may impact on yield (Figure 72).

At Terrington (site 11), in 2016, no yield responses were observed due to low disease. At Boxworth (site 10), yield responses for all products relative to the untreated control (untreated yield = 2.52 t/ha) ranged from 0.28 to 0.62 t/ha. Increasing the dose above half of the recommended label rate did not generally improve yields further (Figure 73).

Due to the relatively late onset of the phoma epidemic in 2017, although cankers developed, there was little impact on yield at either site and results are not reported. In 2018, yield responses ranged from 0.06 to 0.29 t/ha at Rosemaund (site 24) and from 0.12 to 0.87 t/ha at Terrington (site 25) (Figure 74).

Following a cross site analysis of 3 years data, where the epidemic was moderate to severe, the yield response to fungicides was 0.36 to 0.49 t/ha at half recommended label rate and 0.36 to 0.56 t/ha at full recommended label rate (Figure 75).

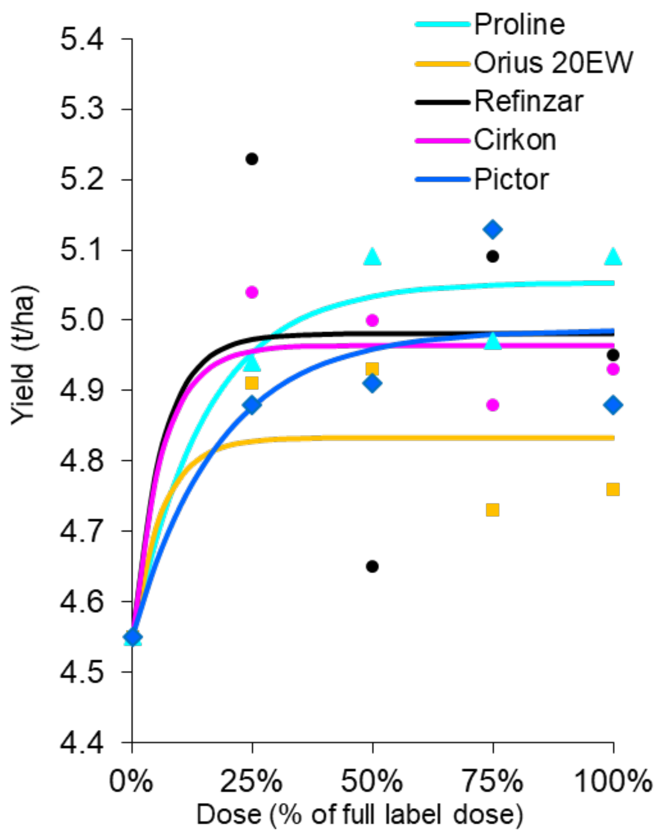

Figure 72: Fungicide dose-response curves for yield in phoma stem canker trials in 2015 (Terrington, site 4).

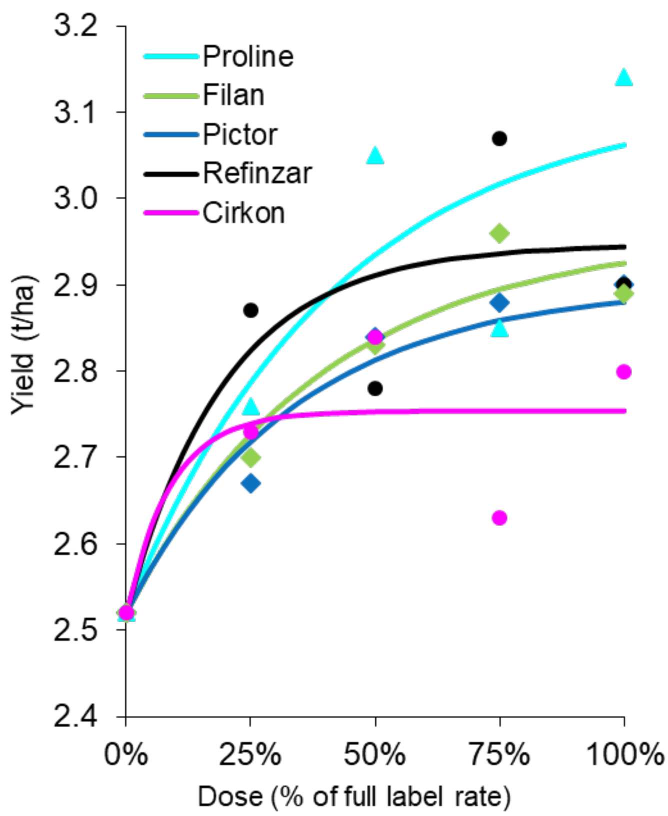

Figure 73: Fungicide dose-response curves for yield in phoma stem canker trials in 2016 (Boxworth, site 10).

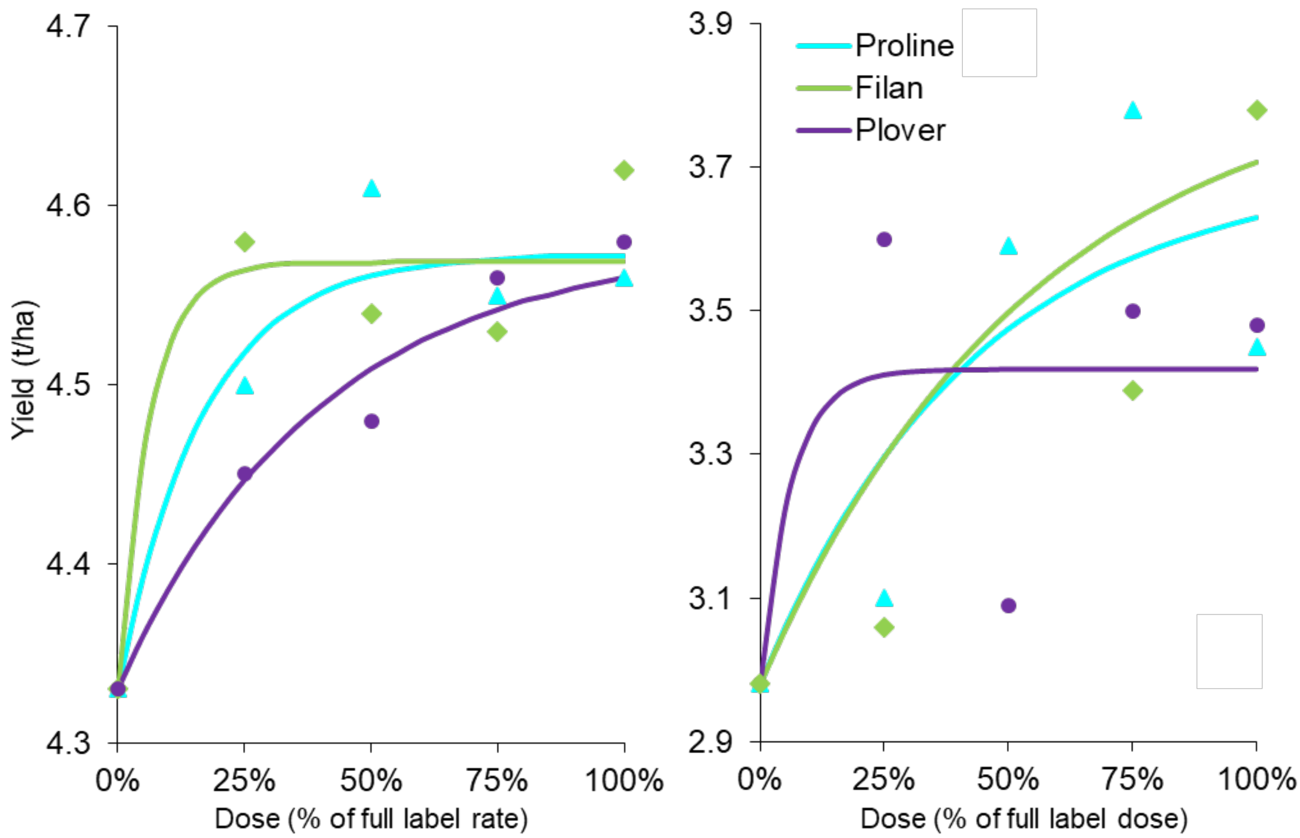

Figure 74: Fungicide dose-response curves for yield in phoma stem canker trials in 2018. Left: Rosemaund, site 24, Right: Terrington, site 25. Plover is restricted by a maximum total dose equivalent to a full rate application. Therefore, the 2 spray programmes exceeding 2 x 0.5 rate are above the maximum recommended dose. Note the charts have different axes.

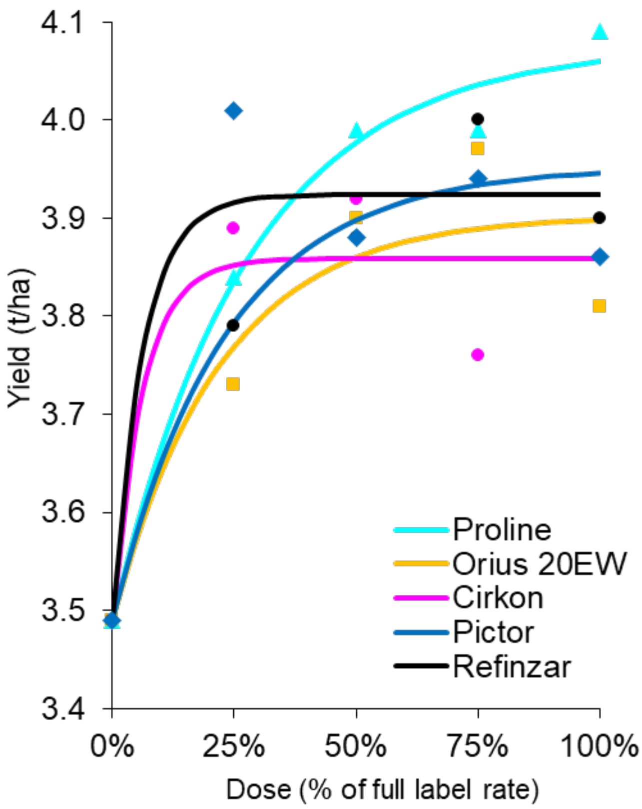

Figure 75: Fungicide dose-response curves for phoma stem canker – cross site analysis using trials with moderate to high canker indices (greater than index 40) in 2014 – 2016.

Summary

The results presented here demonstrate that good control of stem canker is usually achievable as a two spray programme and using at least half the recommended label rate for most products. Both disease risk and crop size are important when deciding on the appropriate product for phoma control and this is demonstrated by data from individual sites in 2015 and 2016. During this project, the first non-azole for autumn phoma control, Refinzar was approved. Refinzar has now been withdrawn but remained in the trials (until registration was withdrawn) for comparison with other products, showing similar activity to Proline. Filan, another non-azole, has also been shown to deliver equivalent control of stem canker to Proline. Orius 20EW and Cirkon appeared to be weaker overall on stem canker, however, yields were generally similar to other products for Cirkon; for Orius 20 EW, negative effects of higher doses (three-quarters of the recommended rate and above) were observed at one site where plants were small.

4.3.1. Light leaf spot

Disease control

In 2015, fungicides were applied on 24 November and 17 February at the trial site near Malton, North Yorkshire and 29 October and 15 March in Midlothian (Figure 76). Data from the Dorset site is not included as no differences between fungicide treatment and the untreated control were observed. Light leaf spot was observed early in North Yorkshire and fungicides were applied before stem extension at this site. At the Malton site, disease severity was moderate with over 13% leaf area affected in the untreated control. Fungicide treatment decreased light leaf spot severity by between 60 and 85%. Proline, Pictor and Orius 20EW appeared to be as effective against light leaf spot at all rates tested, whereas the decrease in light leaf spot severity appeared to be more dose dependent for Refinzar, Cirkon and Orius P, with at least half of the recommended label rate needed to achieve more than 60% control. At Midlothian, between 40 to 50% control of light leaf spot was achieved by fungicides.

In 2016, the percentage of control achieved by fungicides was lower relative to the untreated control when compared to 2015. Fungicides were applied on 26 November and 12 February at the trial site near Malton, North Yorkshire, 25 November and 26 February in Midlothian and 23 November and 25 February in Dorset, again with the later sprays applied prior to stem extension. The most effective treatments provided less than 50% control of light leaf spot (Figure 77). For Cirkon and Proline, light leaf spot control was similar at all doses tested. For Orius 20 EW, Refinzar and Pictor, all appeared to be slightly more effective at the higher rates (from half the recommended label rate upwards) tested compared to lower doses, however, this difference, when considering the attributed decrease in light leaf spot severity, was small.

A two year cross site analysis on five experiments from 2015 and 2016 is shown in Figure 78. Although no significant differences were observed between products or doses, it demonstrates that all products provide between 50 and 60% control of light leaf spot when using at least half of the recommended label rate.

In 2017, there was a change in experimental design across all three sites in order to investigate whether fungicide application timing was important. Due to low disease pressure, it was not possible to produce dose response curves. It was possible, however, to statistically analyse the effect of fungicide application timing on disease severity across all three sites. It was shown that all fungicides provided some control of the autumn and spring phase of the epidemic, however, this was less than the 50 to 60% control usually observed (Figure 79).

In 2018, there was insufficient disease pressure to provide data on product efficacy.

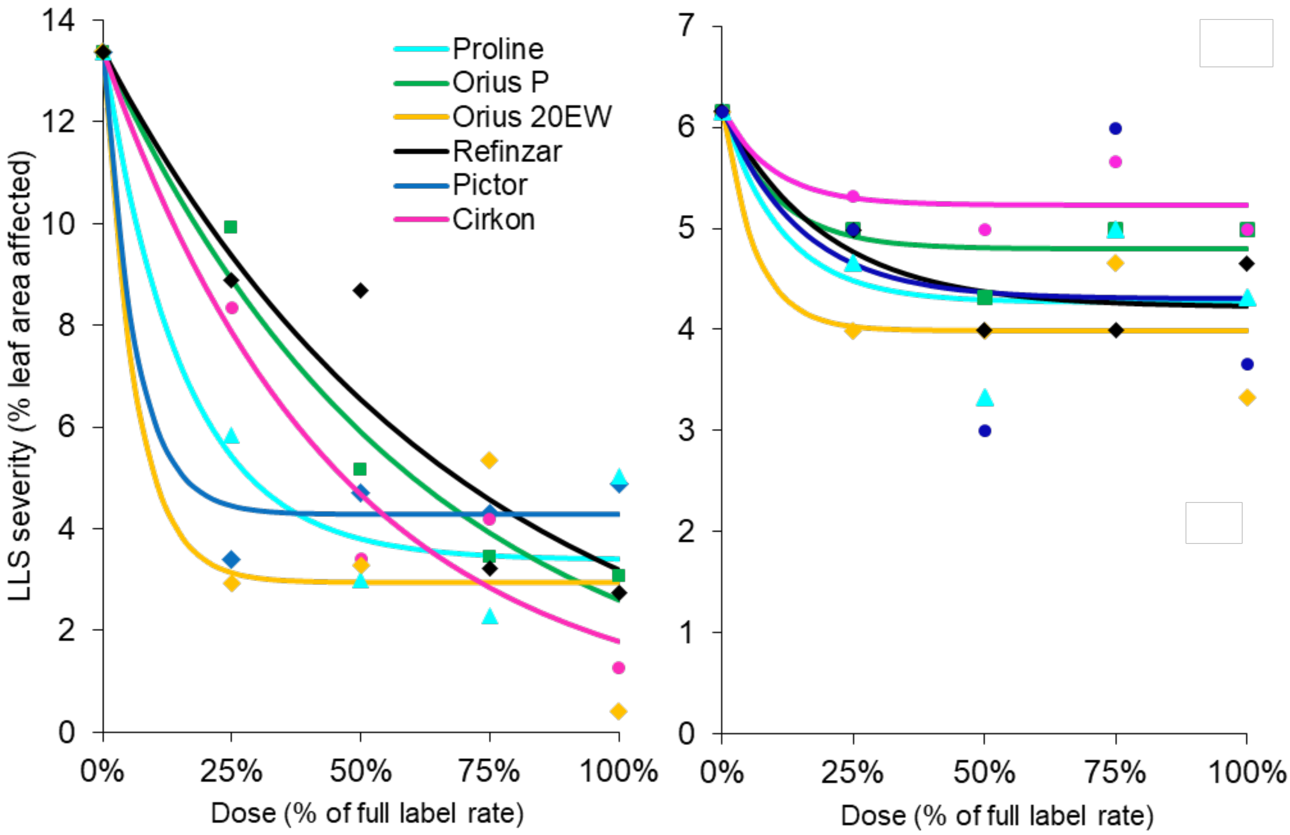

Figure 76: Fungicide dose-response curves for light leaf spot control in 2015. Left: site 1 (Malton). Right: site 2 (Midlothian).

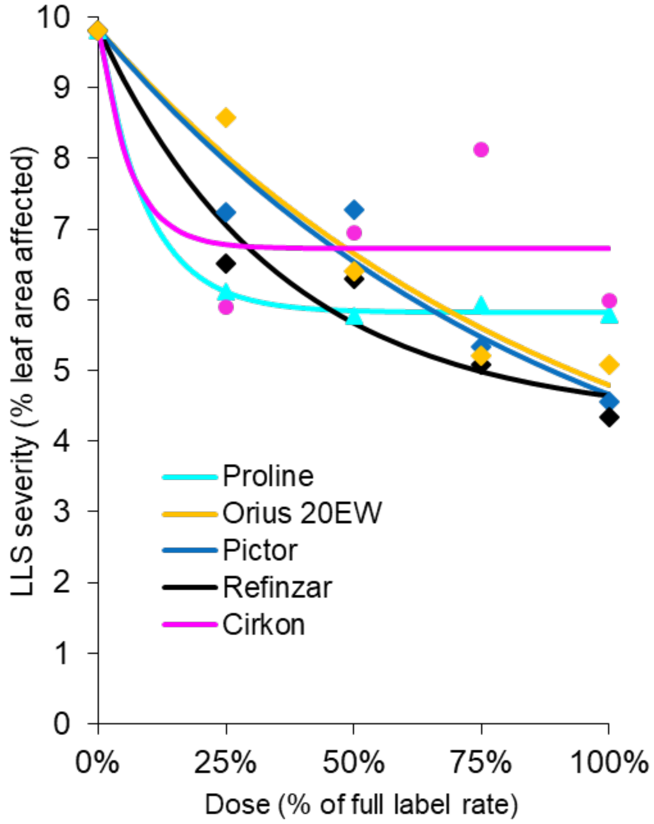

Figure 77: Fungicide dose-response curves showing light leaf spot control at site 9 (Malton) in 2016.

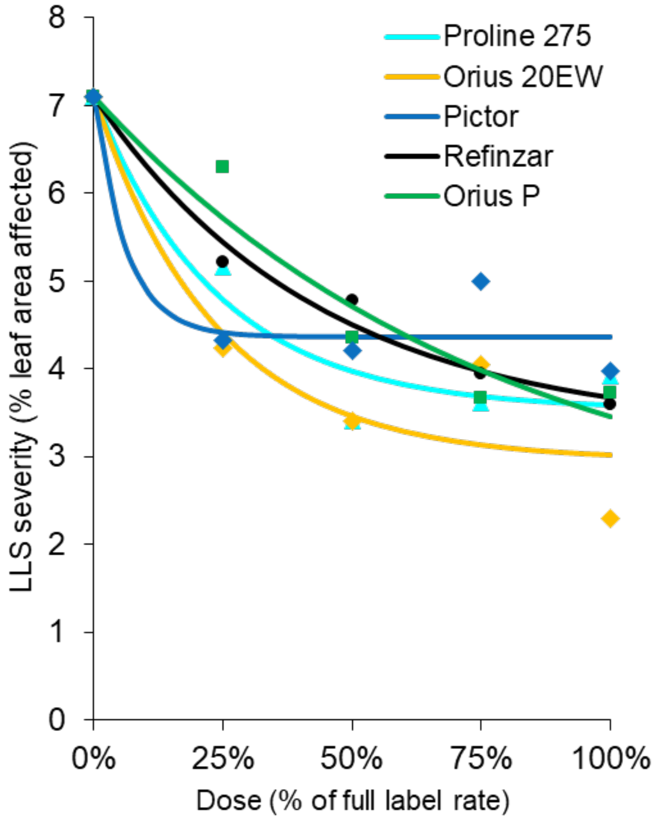

Figure 78: Fungicide dose-response curves for light leaf spot control, averaged over five sites in 2015 and 2016. Orius P is included from 2015 trials only.

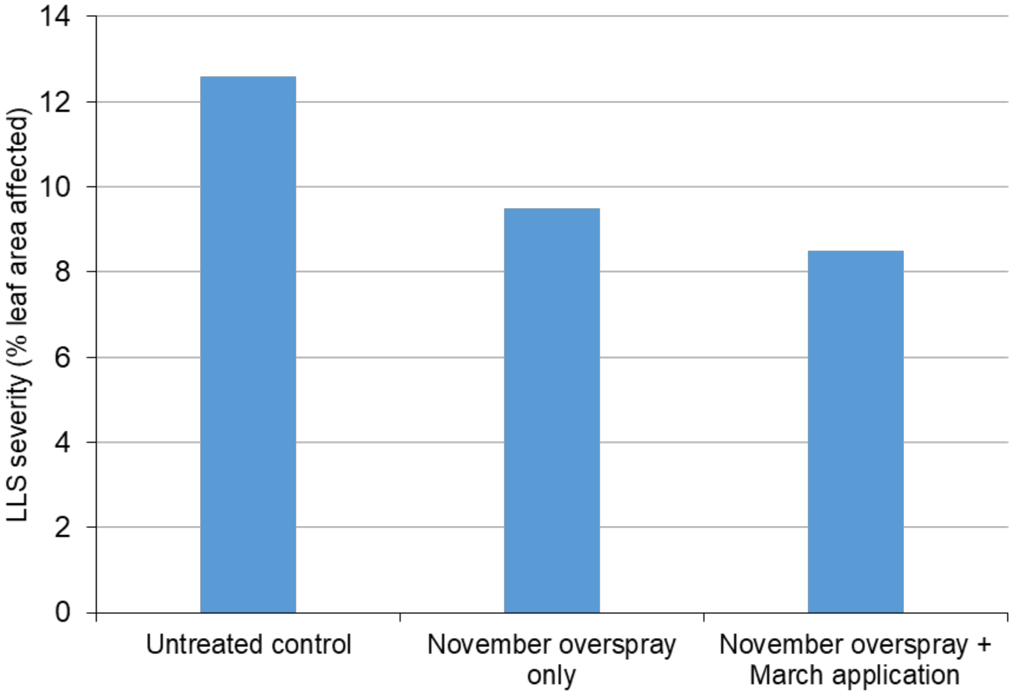

Figure 79: The effect of fungicide timing on the control of light leaf spot in 2017 averaged across 3 sites. Overspray applied in November 2016 and stem extension treatments in early March 2017, typically at GS30.

Yield

At Midlothian (site 2) in 2015, there were significant yield improvements of up to 1.1 t/ha over the untreated control (3.95 t/ha) and up to 0.3 t/ha at Malton (site 1) (Figure 80). At Malton, increasing the fungicide dose beyond half of the recommended label rate did not result in additional yield. At the Midlothian site, there were yield increases of up to 0.2 t/ha observed when higher doses were used, however, this was dependent on the product applied. Yield responses of between 0.08 to 0.40 t/ha were observed at Malton (site 8) in 2016 (untreated = 2.52 t/ha) (Figure 81).

A cross site analysis was conducted for light leaf spot control and yield, including data from all six experiments conducted in 2015 and 2016 (Figure 82). Similar to previous cross site analyses, all treatments significantly decreased light leaf spot compared to the untreated control. Products performed comparably, with average yield responses to the two spray fungicide programmes of up to 0.44 t/ha (untreated = 3.41 t/ha).

An analysis across all sites in 2017 showed that there was a significant effect of fungicide timing on yield, with control of the autumn/winter phase of the epidemic having the greatest impact on yield; November oversprays contributed 0.35 t/ha in yield (Figure 83). The March treatments were responsible for an additional 0.05 t/ha which was unusually low and likely to be due to the generally drier spring, particularly during April, which prevented a substantial epidemic. Due to the slow epidemic, no yield data for 2018 is available to demonstrate differences in relation to fungicide efficacy.

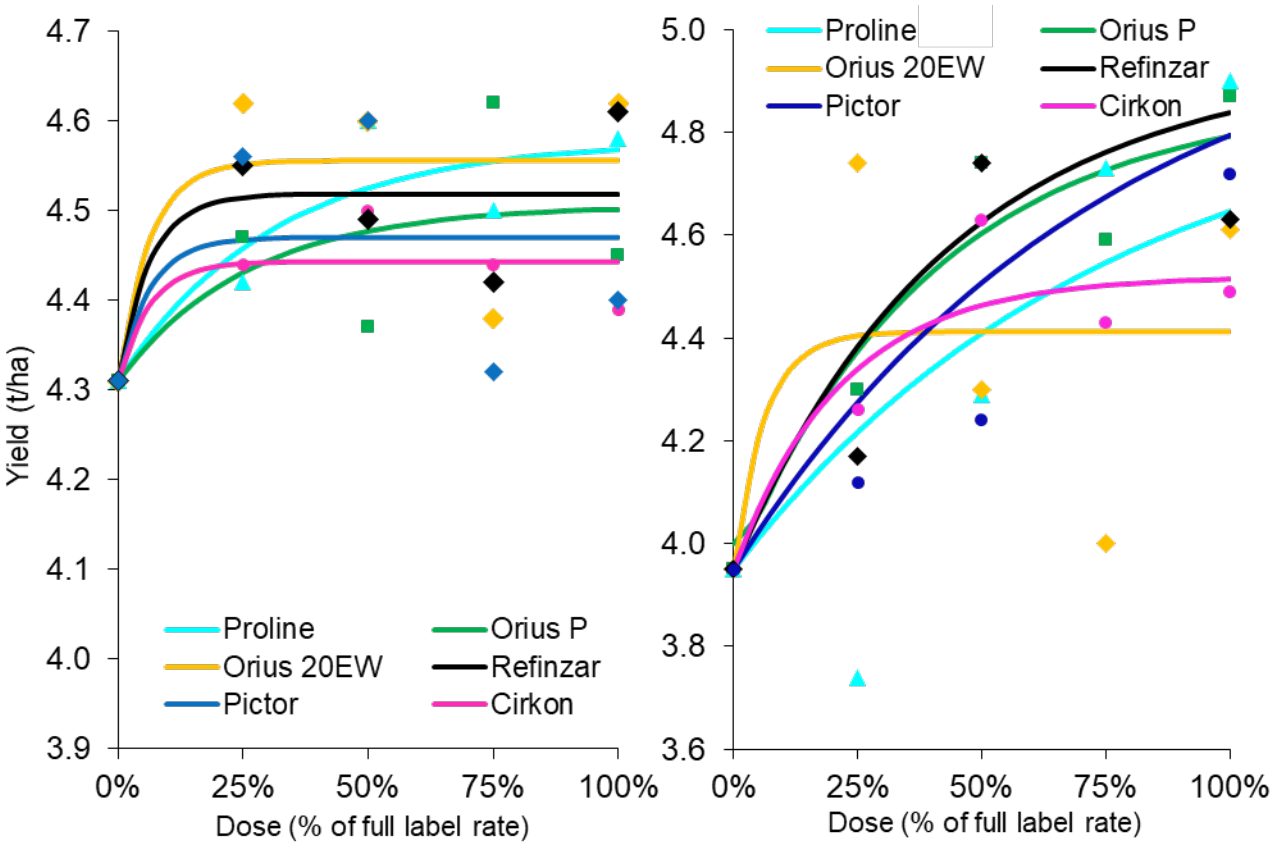

Figure 80: Fungicide dose-response curves for yield in light leaf spot trials showing variations between sites in 2015. Left: site 1 (Malton), Right: site 2 (Midlothian). Note the charts have differing axes.

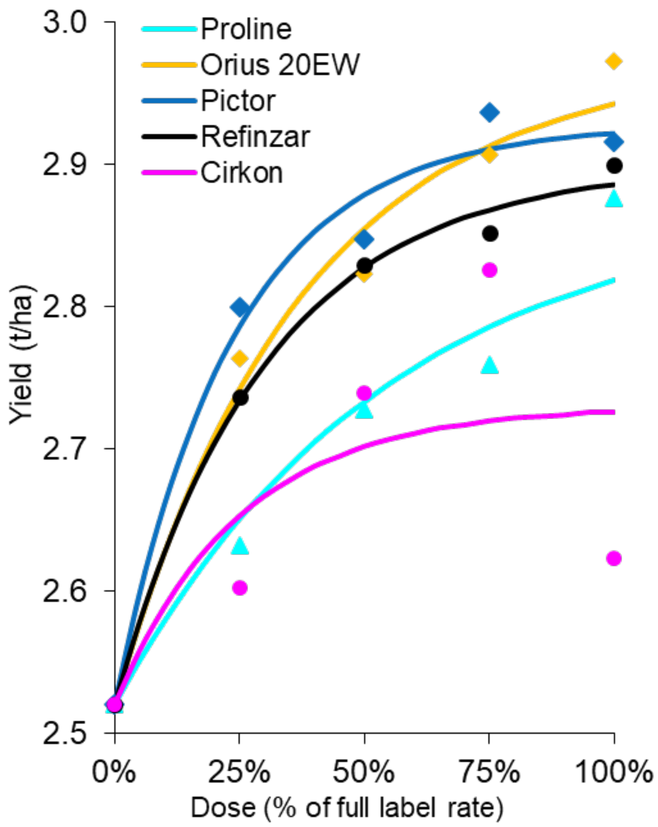

Figure 81: Fungicide dose-response curve for yield in light leaf spot trials in 2016 (Malton, site 8)

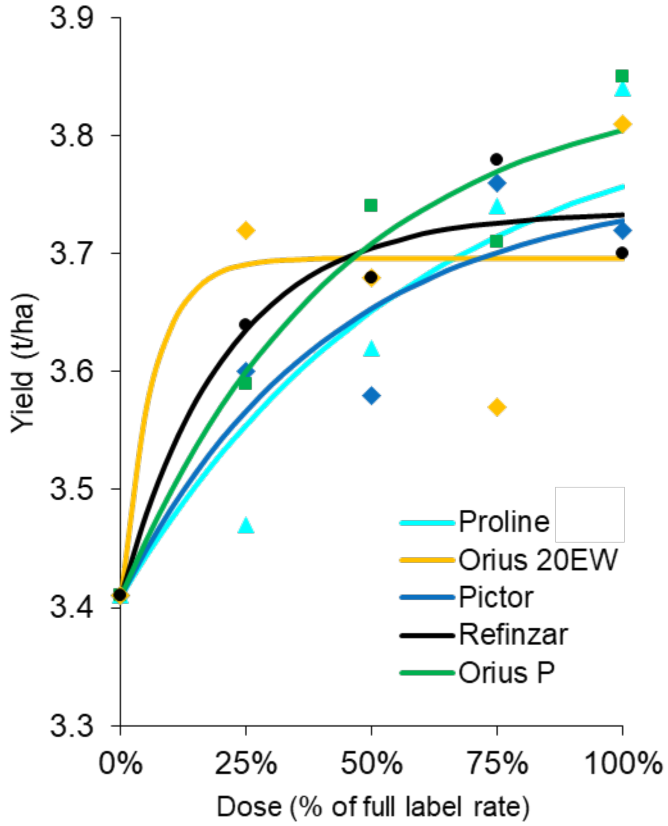

Figure 82: Fungicide dose-response curves for yield in light leaf spot trials, averaged over five sites in 2015 and 2016. Orius P is included from 2015 trials only.

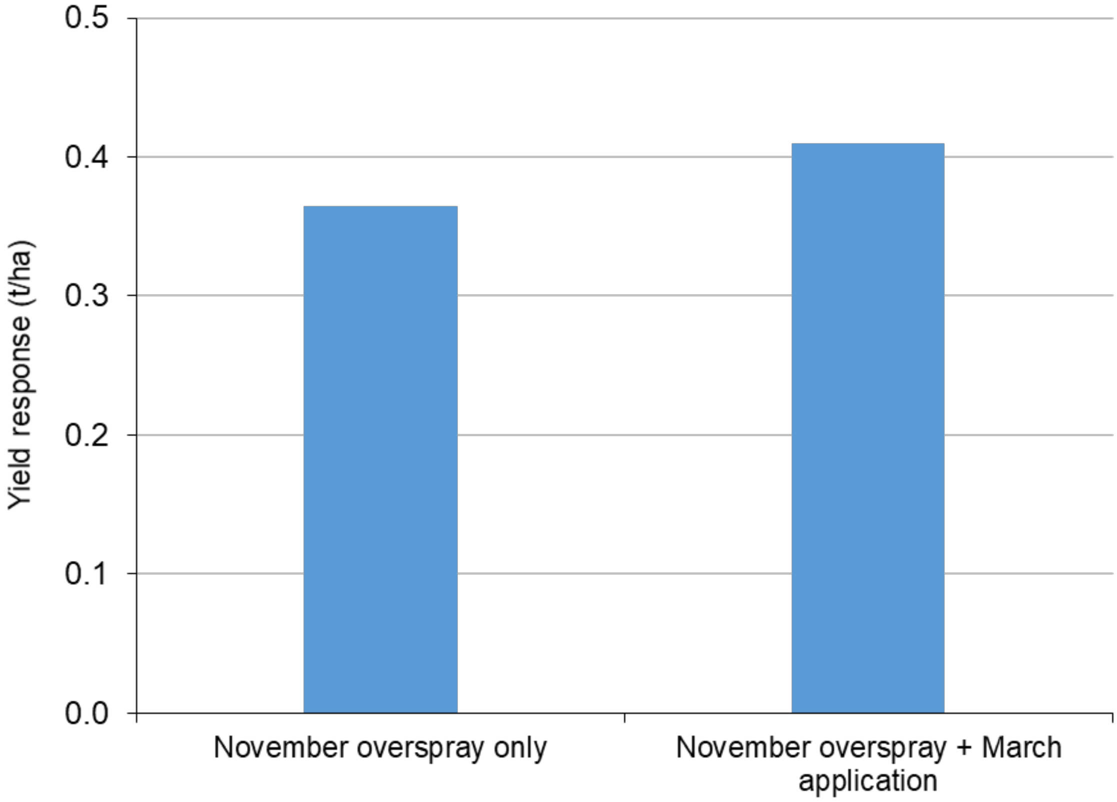

Figure 83: Yield responses (t/ha), compared to the untreated control, across all three sites. P = 0.012, LSD for comparison of treatments with the untreated control (untreated control equals 0 as data are presented as the yield response) = 0.304.

Summary

These experiments show that good control of light leaf spot is difficult to achieve. Some sites have shown yield benefits from using application rates above 50% of the recommended label dose but others have not. Yield increases in response to product dose were variable between sites and years. For increased efficacy at high disease pressure sites, higher doses may be necessary, but this does not always translate into yield responses in the trial series. Product choice will also be influenced by requirements for phoma activity and/or plant growth regulation of large plants (e.g. metconazole or tebuconazole products) and label restrictions. Some flat dose response curves were noted at sites where fungicides with PGR products were used at high doses on small plants in Scotland.

4.3.2. Sclerotinia stem rot

Disease control

In 2015, fungicides were applied on 23 April at the site in Cardigan (site 6). Sclerotinia stem rot levels were moderate (20% plants affected) in the untreated control when assessed on 19 June. All fungicides and doses significantly decreased sclerotinia stem rot giving over 90% control (Figure 84). It is likely that sclerotinia infection occurred very shortly after fungicides were applied, which would be consistent with the lack of differences between doses for disease control or yield. Up to 1% disease was observed in the untreated control in Herefordshire (site 5), therefore this data has been omitted.

In 2016, moderate levels of disease were recorded in the two trials, one in Herefordshire (site 12) and the other in Cardigan (site 13). Filan, Pictor, Proline and Amistar performed similarly at the Herefordshire site. A similar result was observed at Cardigan (site 13), however, Amistar data from the Cardigan site were not included in analyses (Figure 85).

In 2017, fungicides were applied on 14 April to the trials in Herefordshire (site 19) and Ceredigion (site 20). Moderate levels of sclerotinia stem rot were observed at the two sites: 10% plants affected in Cardigan and 35% plants affected in Herefordshire (Figure 86). Proline and Filan appeared to control disease slightly more effectively than Amistar, although all treatments showed good disease control.

Combining the results from the five moderately infected trials from across both sites in 2015, 2016 and 2017 demonstrated the benefits of mid-flowering fungicides, with between 75% and 100% control achieved at the higher doses (Figure 87). Proline, Pictor and Filan showed a greater activity compared to Amistar.

No disease was observed at either site in 2018.

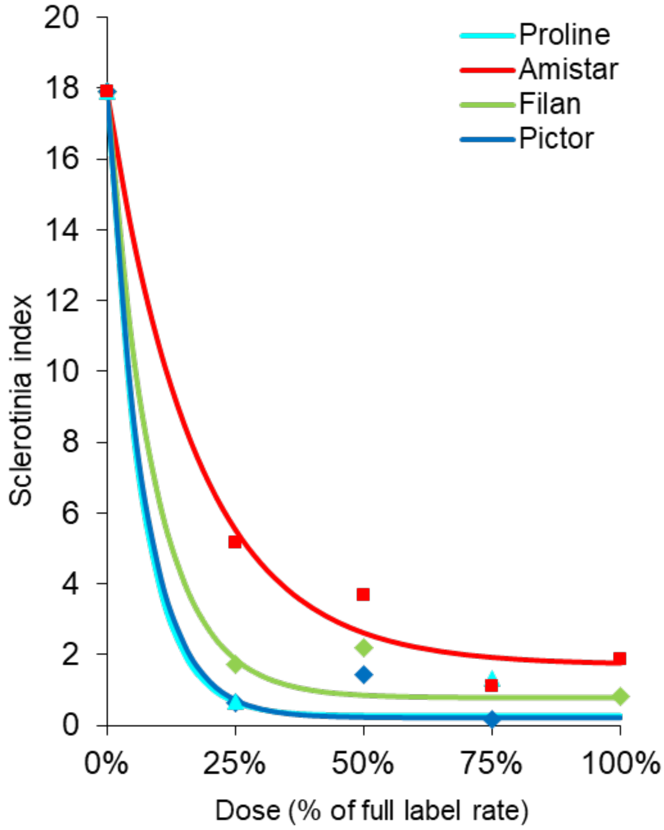

Figure 84: Fungicide dose-response curves for sclerotinia stem rot control in 2015 (Cardigan, site 6).

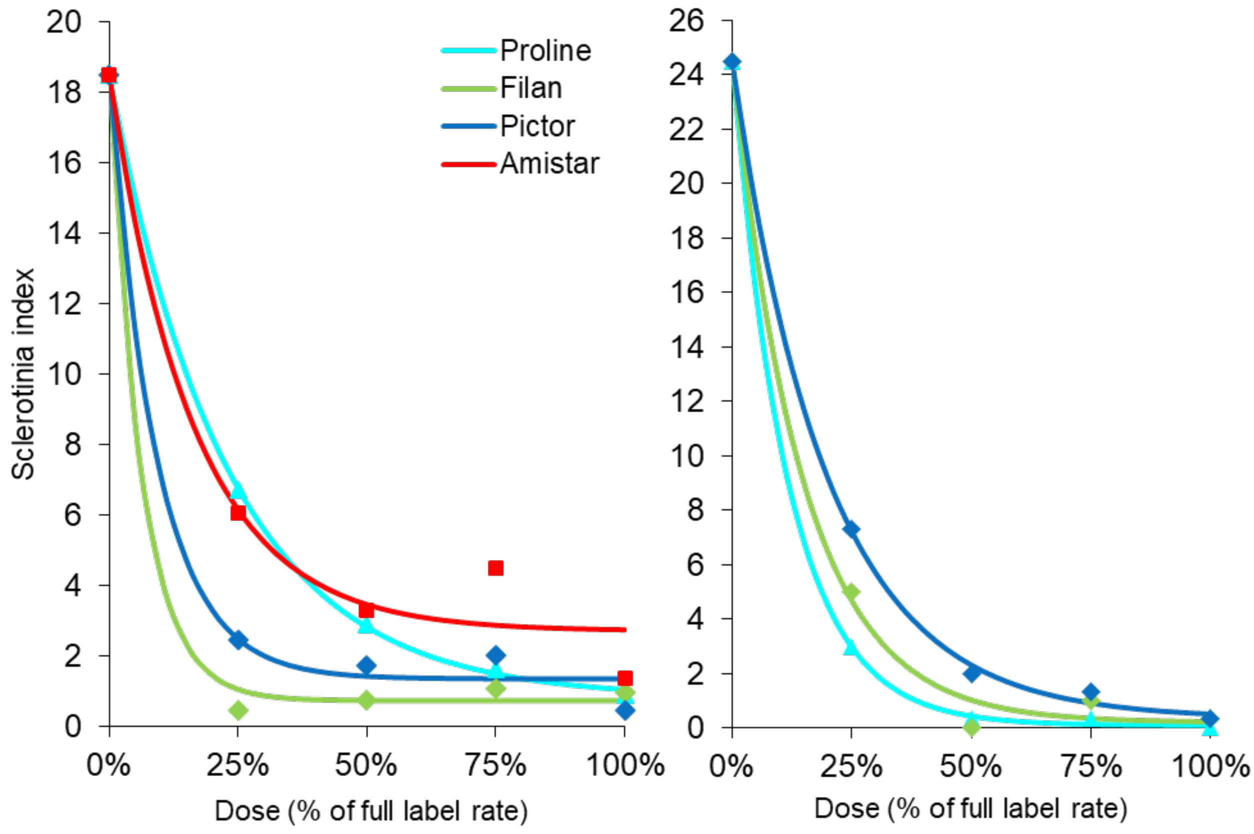

Figure 85: Fungicide dose-response curve for sclerotinia stem rot control in 2016. Left: Rosemaund, site 12, Right: Cardigan, site 13. Note the charts have differing axes.

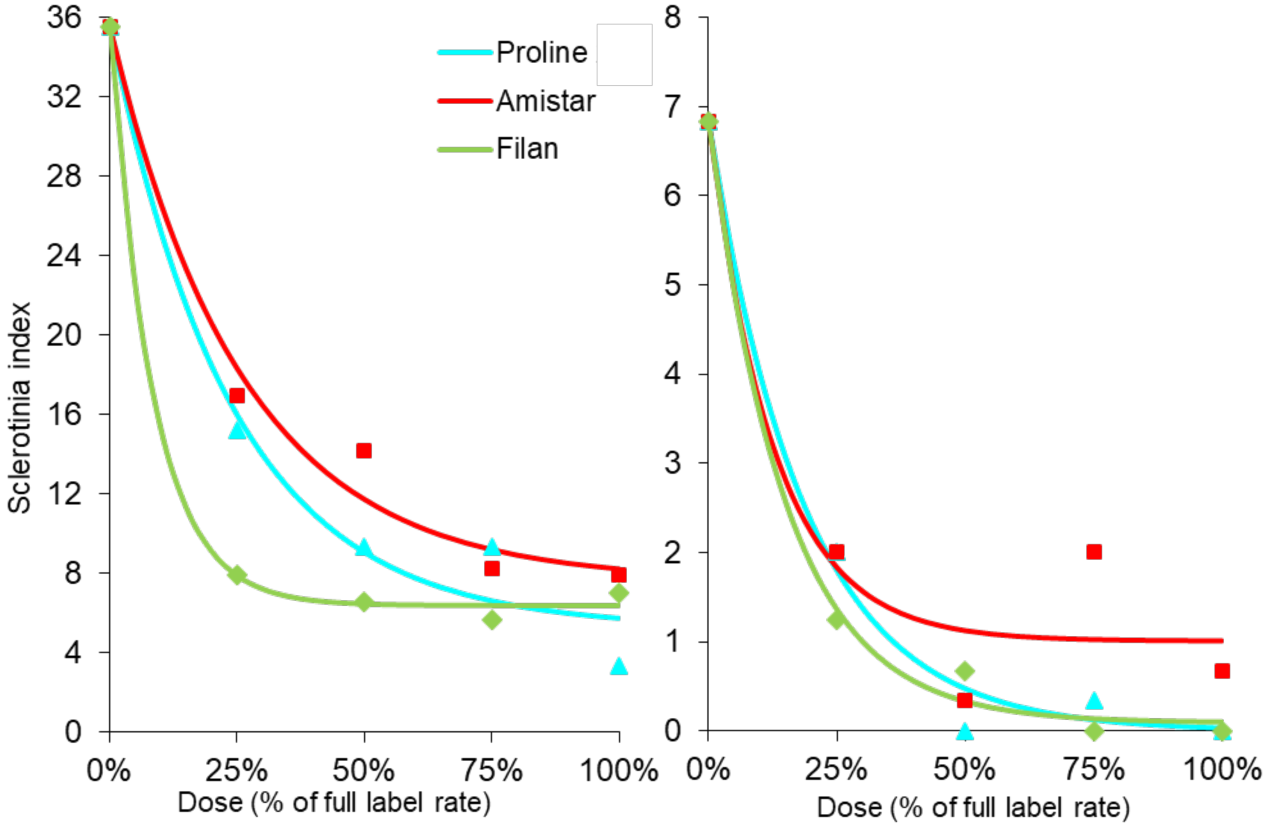

Figure 86: Fungicide dose-response curve for sclerotinia stem rot control in 2017. Left: Rosemaund, site 19, Right: Cardigan, site 20. Note the charts have differing axes.

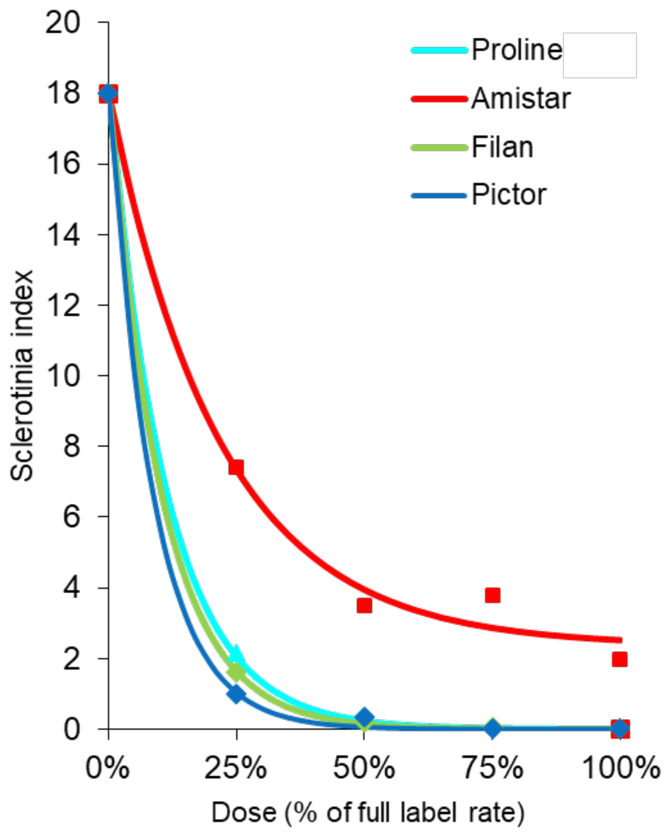

Figure 87: Fungicide dose-response curves for sclerotinia stem rot control. Results averaged over 5 moderately infected trials across sites in 2015, 2016 and 2017.

Yield

In 2015, yield responses ranged from 0.7 to 1.2 t/ha depending on product and dose (Figure 88). Amistar appeared to show the weakest yield response consistent with the levels of disease control provided. In 2016, yield responses were lower, with between 0.5 to 0.7 t/ha depending on the site (Figure 89). Relative rank order of products was not consistent between sites.

In 2017, yield responses at the Cardigan site were low (0.1 to 0.2 t/ha), with an average response of 0.6 t/ha for all commercially available products at the Herefordshire site (Figure 90). Combining the results from the five moderately infected trials from across both sites in 2015, 2016 and 2017 demonstrated the benefits of mid-flowering fungicides, with between 75% and 100% control achieved at the higher doses and yield responses of up to 0.6 t/ha (Figure 91). As observed in the average relative disease control, Amistar showed a slightly reduced yield response in comparison to the other treatments, which were comparable.

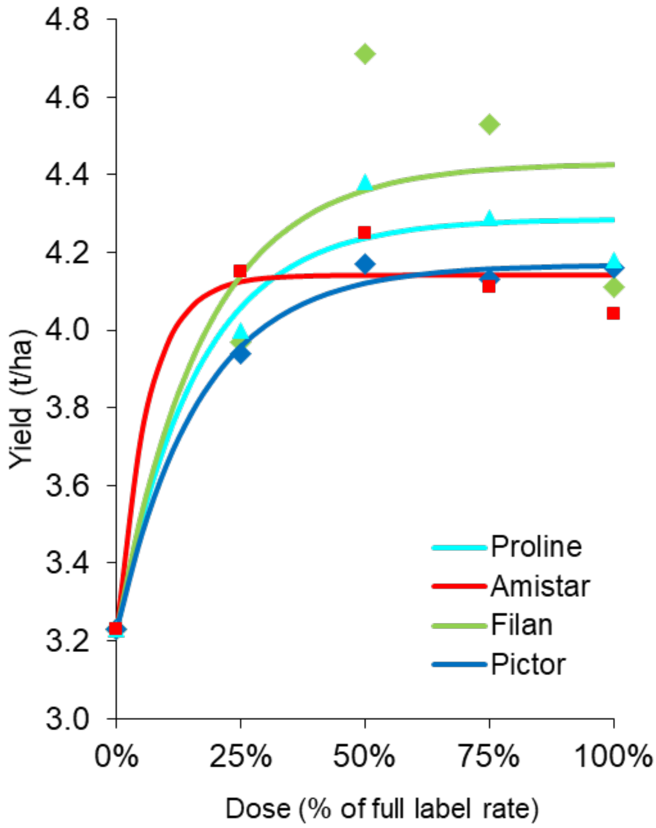

Figure 88: Fungicide dose-response curves for yield in sclerotinia stem rot trials in 2015 (Cardigan, site 6).

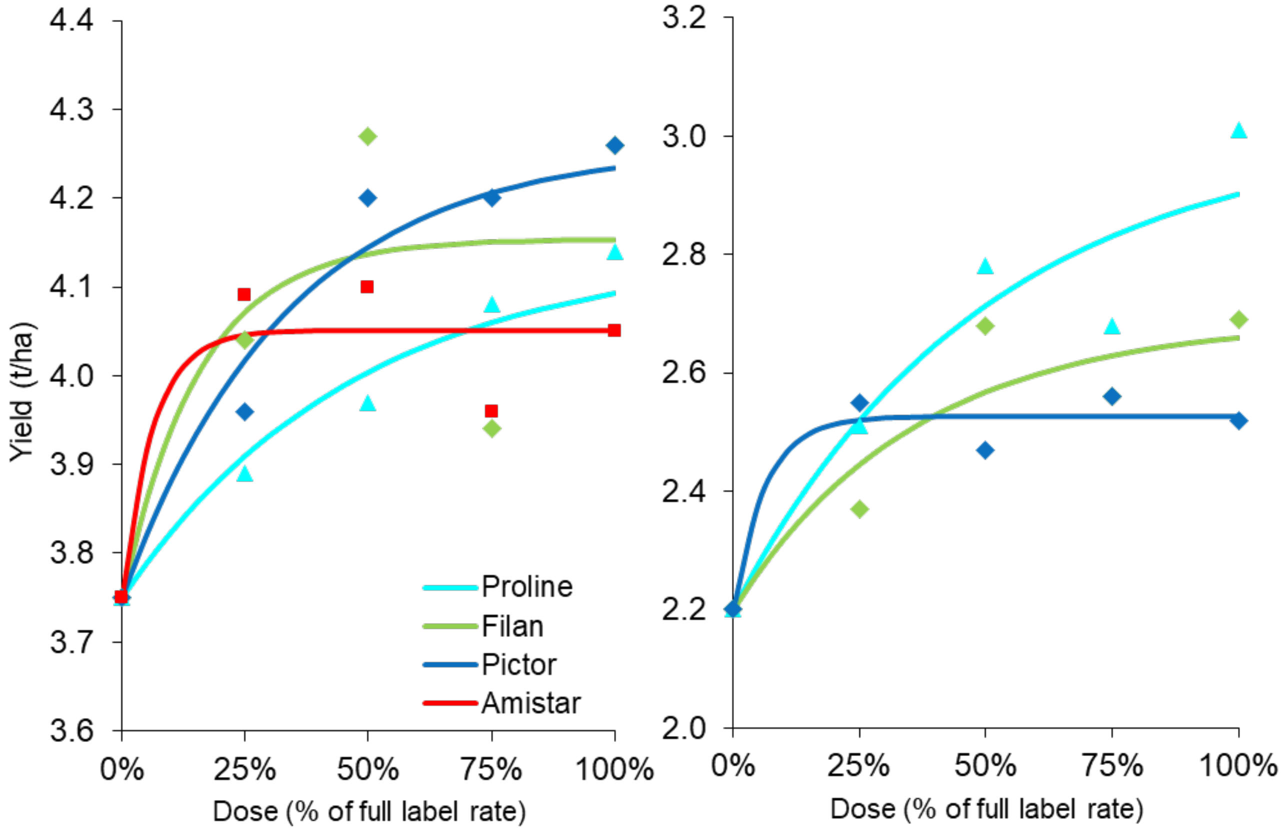

Figure 89: Fungicide dose-response curves for yield in sclerotinia stem rot trials in 2016. Left: Rosemaund, site 12, Right: Cardigan, site 13. Note that the axes on each chart differ.

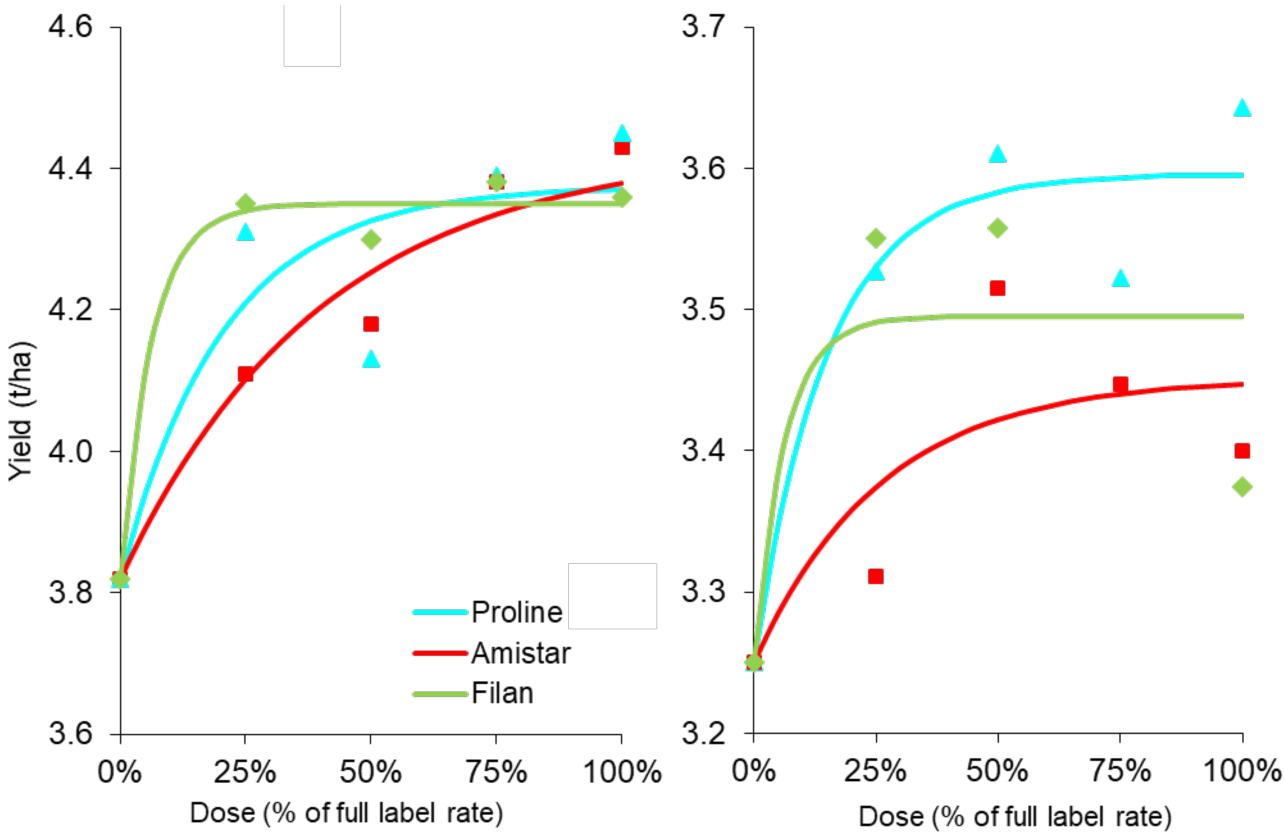

Figure 90: Fungicide dose-response curves for yield in sclerotinia stem rot trials in 2017. Left: Rosemaund (site 19), Right: Cardigan (site 20). Note, the axes differ on each chart.

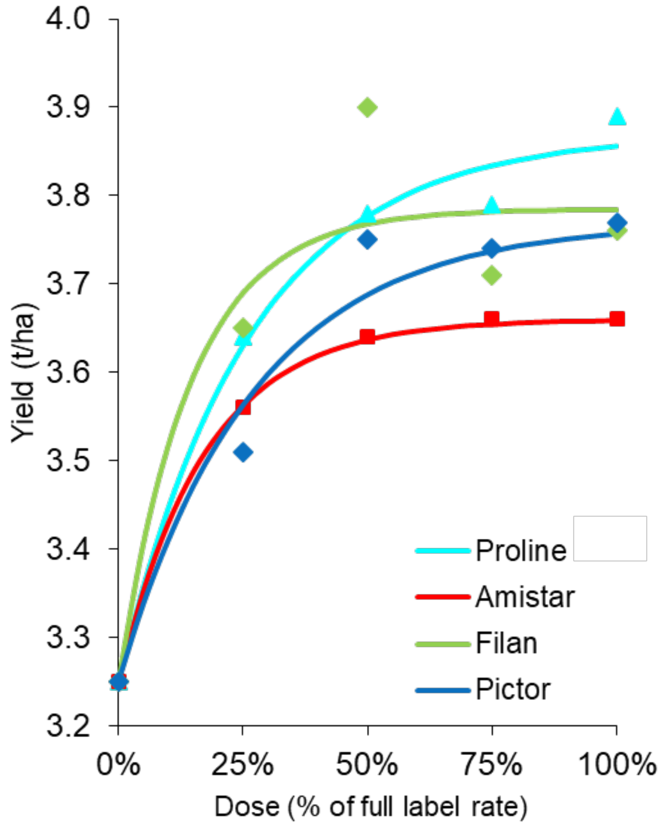

Figure 91: Fungicide dose-response curves for yield in sclerotinia stem rot trials. Results averaged over 5 moderately infected trials across both sites in 2015, 2016 and 2017.

Summary

Only a few of the products tested for sclerotinia control can be reported at this stage, as the majority of the treatments in the trials were experimental products and data from these cannot be published until the product(s) are registered. Across the years, Filan, Pictor and Proline performed similarly, providing slightly better control than Amistar; these differences were small and all products should be considered to be effective against sclerotinia. Very good control of sclerotinia can be achieved by a well-timed single fungicide application, protecting from substantial yield losses, although it is clear that the yield benefits from applying fungicides will vary from year to year. In these experiments, at least 50% of the recommended dose was required to protect yield, and previous Fungicide Performance experiments at high pressure disease sites has suggested that at least 75% of the recommended dose should be used to provide control for the majority of the flowering period.

5. References

Blake, JJ, Gosling, P, Fraaije, BA, Burnett, FJ, Knight, SM, Kildea S and Paveley, N. 2017. Changes in field dose–response curves for demethylation inhibitor (DMI) and quinone outside inhibitor (QoI) fungicides against *Zymoseptoria tritici*, related to laboratory sensitivity phenotyping and genotyping assays. *Pest Management Science.* **74**(2), 302-313.

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