Project Report No. 455

August 2009

Price: £8.50

Appropriate fungicide doses on winter barley: Producing dose-response data for a decision guide

by

SJP Oxley[1] and EA Hunter[2]

[1]SAC, West Mains Road, Edinburgh EH9 3JG
[2]Biomathematics & Statistics Scotland, James Clerk Maxwell Building, The King's Building, Edinburgh, EH9 3JZ

This project commenced on 1st August 2004. The work was funded by a contract for £239,831 from HGCA (Project 3027). The project was later extended for a further 18 months from 1st September 2007.

Contents

Abstract

The aim of the research was to provide an independent source of information about the activity of current and newly introduced fungicides. The diseases investigated were rhynchosporium, brown rust, powdery mildew, net blotch and ramularia. Protectant and eradicant properties were measured in field trials carried out throughout the UK and Eire under high disease pressure conditions. The efficacy of fungicides does not remain static, and the results on disease control from this research can be used alongside other evidence to highlight situations where the efficacy of disease control may be changing in the field. It was important to ensure growers received the most up to date information about the activity of fungicides, so the research aimed to deliver the results to growers annually at HGCA Disease Roadshows.

The project has shown that the fungicides Proline, Fandango and Tracker provide the core components to manage barley diseases and achieve optimum. Two new experimental fungicides are potentially a major step forward in the control of net blotch and brown rust and also provide an alternative option to control ramularia leaf spot. Yield responses are similar to the most effective fungicides currently available. For powdery mildew control, Flexity, Torch extra and Cyflamid continue to show effective control, but Talius has not performed as well.

Getting the results out to the HGCA members quickly meant the procedures in assessing trials, collecting data, analysis and dissemination were all focussed on achieving this aim. This research collected four years' data. A previous project collected three years' data. Together these data provide a useful foundation for future research, providing good field efficacy information on the seasonal and long term changes in fungicide performance as well as a baseline to compare new fungicides.

Results were reported in a Scottish Government funded Technical Note entitled "Barley Disease Control". This note placed the appropriate dose data in a practical context of managing barley diseases. More effective ways of getting the information across to growers were developed as part of a Fungicide Performance Dose Curve Generator. Therefore a web-based tool allows growers to compare dose curves generated from seven years' study of different fungicides.

Summary

Fungicides and varietal resistance are the two key components which influence disease management in winter and spring barley in the UK. Testing of new varieties for national listing is carried out by Defra in the UK. Further testing of varieties to produce a recommended List (RL) is organised by the Home-Grown Cereals Authority through Crop Evaluation Ltd (CEL). This research project focuses on the fungicide component and the key aim is to provide an independent source of information on the activity of current and recently “Approved” fungicides against the main barley diseases.

Over this four-year project, twenty four winter barley field trials were carried out in the UK in addition to the sixteen from the previous three year project. The RL uses robust fungicide programmes to achieve the genetic potential of varieties. This research uses the most susceptible varieties in high risk disease situations to assess the potential of fungicides. The trials rely on natural infection.

The diseases targeted were rhynchosporium, brown rust, powdery mildew and net blotch. Eight spring barley trials in Scotland and Eire, in addition to the three trials from previous work, targeted the leaf spotting complex caused by ramularia and also by physiological stress.

The field trials were managed using typical local inputs of herbicides, fertiliser and plant growth regulators. Fungicides were applied just once to the crops at quarter, half, full and double the “Approved” labelled dose for barley. The trials also included untreated control plots. For the purposes of creating dose response curves, it was important to determine the level of control at the double dose. Growers must not however exceed the label dose in commercial situations and many of the graphs in the report only show values up to full dose. Timing of the fungicide was generally between GS32 (2 nodes detectable) and GS39 (Flag leaf fully emerged). The timing of the fungicide was dependent upon the start of visual symptoms of disease. Crops were assessed for disease at the time of treatment. The leaf, fully emerged at the time of treatment, was tagged. Following treatment, at least two assessments were carried out at approximately three and six weeks after treatment. Assessments were carried out for each leaf layer. Disease assessments of the leaves emerged at the time of treatment were reported as eradication, whilst disease assessments on the upper unfurled leaf and other developing leaves following treatment were reported as

disease protection. Green leaf area assessments were carried out at the same time as the disease assessments. At harvest, the plots were yielded and specific weights recorded.

This experimental approach is a severe test for fungicides. It is particularly severe for fungicides which may have a narrow disease spectrum, or narrow protectant or eradicant activities. Such issues have been addressed in a previous HGCA-funded research project (Project Report 315) which looked at the contribution specific fungicides have in mixtures. This has also been addressed in a recently completed barley research project focussing on fungicide mixtures (Project Report 436).

Results from the field trials were analysed separately to determine differences between the treatments. Trials were then analysed collectively by year, and then the collective data for the last two years (2007-8), the last three years (2006-8) and all four years (2005-8) was analysed. The four years averaged together would provide the largest data set, but it is only valid if the efficacy of the fungicides had remained stable over that time. Yearly results can vary and poor control should not automatically lead to a conclusion of a decline in efficacy. One reason for year to year variation is the different levels of disease pressure in each season. Getting 100% control in a year where disease levels are low is a more straightforward task for a fungicide than getting 100% control where levels are very high. Before any resistance changes can be assumed, there has to be other evidence, for example, from sensitivity testing. During the first period of this research in 2002-2004, strobilurin (QoI) resistance to powdery mildew developed from a low level to a high level. In 2004, there was evidence that resistance to QoI fungicides had occurred to net blotch, so field activity in the period following this has been measured. Rhynchosporium resistance to the triazole fungicide epoxiconazole (Opus) has been reported and has currently stabilised (HGCA Research Report 315). Reports from France in 2008 indicated the presence of Rhynchosporium resistant to QoI fungicides. To date, this has not been detected in the UK, but future work will help determine whether this becomes sufficiently widespread in the UK to affect field performance of this group of fungicide.

Curves were fitted to the results and an appropriate fungicide dose curve generator has been developed to allow access to the individual curves for disease protection, eradication, green leaf area, yield, specific weight and value for money via the World

Wide Web. Each December since then the database underlying the curve generator has been updated with that seasons harvest results. This approach allows levy payers fast access to new data on an annual basis.

Winter Barley

Key results

Fungicide activity for disease protection and eradication has been detailed in Table 1 on the basis of a number of plus signs, with four plus signs giving best control. The plusses have been derived from the level of disease control achieved from a half dose. This dose was chosen, since it is one which is easiest for growers to identify as a dose they are likely to use on a crop. It is also a dose for which actual result data exist, making the results more credible than using a dose requiring the response to be defined from the generated curves.

Rhynchosporium

The fungicides Fandango (prothioconazole + fluoxastrobin) and Proline (prothioconazole) continue to achieve the best protection and eradication of rhynchosporium. This was consistent over four years and there appears to have been no slippage in control following their widespread use. Limited results show, based on one year only, the experimental fungicide HGCAB1 to have useful activity against this disease. Tracker (epoxiconazole + boscalid) and Comet (pyraclostrobin) achieved the next best control. Opus (epoxiconazole), Kayak (cyprodinil), Galileo (picoxystrobin) all achieved similar control. Bravo (chlorothalonil) achieved similar levels of disease protection to Opus, but was weak on disease eradication. Torch extra (spiroxamine), in contrast to Bravo, achieved poor protectant activity, but provided similar eradicant activity to Opus.

Table 1 Fungicide activity against the major winter barley diseases

Fungicide	Rhynchosporium eradication	Rhynchosporium protection	Mildew protection	Mildew eradication	Brown rust protection	Brown rust eradication	Net blotch protection	Net blotch eradication	Ramularia protection	Abiotic leaf spot protection
Amistar	-	-	-	-	++	++	++	+	+	+++
Bravo 500	++	+		-	-	-	-	-	+++	++
Comet	+++	+++	+	-	+++	++	+++	++	+	+
Corbel	-	-	+	++	+	+	++	-	-	-
Cyflamid	-	-	+++	++	-	-	-	-	-	-
Fandango	++++	++++	++++	-	+++	++	++	+++	+++	++
Flexity	-	-	++++	-	-	-	-	-	-	-
Fortress	-	-	+	-	-	-	-	-	-	-
Galileo	++	++	-	-	+++	++	++	-	-	-
Kayak	++	++	+++	-	+	+	++	++	-	-
Opus	++	++	+++	-	+++	++	++	++	++	++
Proline	++++	+++	+++	-	+++	++	+++	+++	+++	++
Talius	-	-	++	-	-	-	-	-	-	-
Torch extra	+	++	++++	+++	++	+	+	-	-	-
Tracker	+++	+++	+++		+++	++	++	+	+++	++
Twist SC	-	-	-		-	-	++	+	-	-
Unix	++	++	-		-	-	++	-	-	-
HGCAB1	++++	+++	++		++++	++++	++++	+++	+++	++
HGCAB2	-	-	-	-	-	-	-	-	+++	++

Disease control	Comment
up to 25%	+
25-50%	++
50-75%	+++
75-100%	**++++**
No Data	**-**

Powdery mildew

Powdery mildew eradication was best with Torch extra (spiroxamine). Corbel (fenpropimorph) and Cyflamid (cyflufenamid) also achieved reasonable eradicant activity. The most effective protection was achieved with Flexity (metrafenone), Torch extra (spiroxamine) and Fandango (prothioconazole + fluoxastrobin). Talius (proquinazid) achieved disappointing results in this set of experiments.

Brown Rust

HGCAB1 achieved excellent control of brown rust. Many fungicides achieved very good protection, including Galileo (picoxystrobin), Comet (pyraclostrobin), Opus (epoxiconazole), Tracker (epoxiconazole + boscalid), Proline (prothioconazole) and Fandango (prothioconazole + fluoxastrobin). Torch extra (spiroxamine) achieved good protection, but the activity from Corbel (fenpropimorph) was lower. Kayak (cyprodinil) also achieved poor control. The good control achieved with Proline is in contrast to the control normally achieved with this fungicide for wheat brown rust.

Net blotch

Net blotch data was more evident in the last four years. This may be an indication that the disease is becoming more widespread. HGCAB1 achieved excellent protectant activity alongside Proline (prothioconazole) and Comet (pyraclostrobin). Most other fungicides provide moderate protection. Amistar (azoxystrobin) performed less effectively compared to the other QoI fungicide Comet. Fandango appeared to show better eradicant activity than protectant activity compared to Proline.

Yields

The more broad spectrum fungicides or those fungicides which contained more than one active ingredient in their formulation achieved the best yields. The best yield responses (Table 2) in trials where the dominant disease was net blotch was 1.44 t/ha, rhynchosporium 0.98 t/ha, brown rust 1.64 t/ha and powdery 1.05 t/ha. This shows that without effective methods to control disease, diseases will penalise winter barley yields by 13% - 22% based on an average treated yield of 7.5 t/ha.

Table 2 Yield responses to key fungicides based on different dominant diseases

Net Blotch yields			Mildew yields			Rhynchosporium yields			Brown rust yields		
Fungicide	t/ha	Rating	Fungicide	t/ha	Rating	Fungicide	t/ha	Rating	Fungicide	t/ha	Rating
HGCAB1	7.74	++++	Proline	7.83	++++	Fandango	7.59	+++	Proline	7.38	++++
Tracker	7.39	++++	HGCAB1	7.71	+++	Proline	7.54	+++	Fandango	7.19	++++
Fandango	7.34	++++	Opus	7.6	+++	Tracker	7.4	+++	Comet	7.14	++++
Proline	7.28	+++	Torch extra	7.39	+++	HGCAB1	7.34	+++	Opus	6.88	++++
Comet	7.2	+++	Corbel	7.21	++	Galileo	7.28	+++	Amistar	6.8	++++
Galileo	7.02	+++	Talius	7.08	++	Opus	7.25	+++	Torch extra	6.59	+++
Amistar	6.94	+++	Flexity	7.07	++	Kayak	7.21	+++	Corbel	6.45	+++
Opus	6.93	+++	Cyflamid	6.91	+	Bravo 500	6.98	++	Galileo	6.41	+++
Twist SC	6.9	+++	Fortress	6.86	+	Comet	6.96	++			
Kayak	6.76	++				Unix	6.35	-			
Torch extra	6.69	++									
Unix	6.69	++									
Corbel	6.33	+									
Untreated	6.3		Untreated	6.78		Untreated	6.61		Untreated	5.74	

Best yield

Lowest yield

Yield response	Comment	T/ha
+	Poor yield response	Up to 0.25 t/ha
++	Moderate yield response	0.26-0.5 t/ha
+++	Good yield response	0.51-1.0 t/ha
++++	Very good yield response	>1.0 t/ha

The best yield performers in rhynchosporium trials were Fandango, Proline Tracker and HGCAB1 (limited data). Where brown rust was targeted, Proline, Fandango, Comet and Opus achieved the best results. For powdery mildew, Proline, Opus and HGCAB1 (limited data) achieved the best results.

At the bottom end of the table, Fortress, Cyflamid and Corbel predominate. This is an indication of their specialist uses in disease protection or eradication. A summary of the potential yield benefit from the fungicides tested in this project is given in Table 3.

Green leaf area

Green leaf area was assessed alongside the diseases. This information is summarised in Table 3 and shows which fungicides are most effective at maintaining green leaf area. These effects are not always associated with disease control. Where a fungicide results in better green leaf area, it can be expected that there is an opportunity to get a better yield, but be aware that any diseases which are not well controlled by that specific fungicide, may colonise the green leaf.

Value for money

The margins were calculated by using a grain price of £150/tonne at a specific weight of 63 Kg/hl. The price was adjusted by £1 per tonne for every Kg/hl. The cost of the fungicide was then deducted. Table 3 shows a summary of value based on fungicides used at half dose. Fungicides which rate highly in disease efficacy also achieved the best value for money. Fungicides with a specific use (i.e. powdery mildew) tend to perform less well compared to broad spectrum fungicides. In practical terms, these specialist fungicides will always be used in a mixture.

Table 3 Comparison of fungicides in terms of yield, green leaf area and value for money at half dose

Product label	Yield response	Green leaf area retention	Value for money
Amistar	+++	+++	+++
Bravo 500	++	+++	++
Comet	+++	+++	+++
Corbel	+	+++	+
Cyflamid	+	+++	-
Fandango	++++	++++	++++
Flexity	++	+++	+
Fortress	+	++	-
Galileo	+++	+++	+++
HGCAB1	++++	++++	No data
Kayak	+++	+++	+++
Opus	+++	+++	+++
Proline	+++	++++	++++
Talius	++	+++	+
Torch extra	++	+++	++
Tracker	+++	+++	++++
Twist SC	+++	+++	+++
Unix	+	+++	-

Yield response	Comment	T/ha
+	Poor yield response	Up to 0.25 t/ha
++	Moderate yield response	0.26-0.5 t/ha
+++	Good yield response	0.51-1.0 t/ha
++++	Very good yield response	>1.0 t/ha

Green leaf area retention	Comment	% Green leaf are retention
+	Poor	0-25%
++	Moderate	26-50%
+++	Good	51-75%
++++	Very good	76-100%

Value for money	Comment	Margin over fungicide cost £/ha assuming £150/t
-	-	£950-980
+	Poor	£980-1010
++	Moderate	£1010-1040
+++	Good	£1040-1070
++++	Very good	>1070

Spring barley

Ramularia and abiotic leaf spots

The best control of ramularia was achieved with Bravo, Proline, Tracker, Fandango and the two experimental fungicides (HGCAB1 and HGCAB2). Opus also achieved good control. The QoI fungicides were less effective and the reason for this is now known to be due to resistance from a single mutation (Fountaine & Fraaije 2009). Abiotic leaf spots were reduced with the QoI fungicide Amistar, but the second QoI fungicide (Comet) was less effective. It is possible that the active ingredient or the formulation of Amistar have antioxidant properties which reduce the level of leaf spotting caused by oxidative stress. The two experimental fungicides show good activity and also achieved the best yield response (based on limited data).

Table 4 Summary of disease control, yield and green leaf area from spring barley trials.

Fungicide	Ramularia	Abiotic leaf spots	Green leaf area retention	Yield response
Bravo_500	+++	++	+++	+
Opus	+++	++	+++	++
Proline	+++	++	+++	++
Tracker	+++	++	+++	++
HGCAB2	+++	++	++++	+++
HGCAB1	+++	++	++++	+++
Amistar	+	+++	++	+
Comet	+	+	+++	++
Fandango	+++	++	+++	++

See categories used in winter barley tables above for definition of plus signs (Tables 1, 3)

Technical detail

Introduction

Management of fungal diseases in barley continues to rely on the use of fungicides to achieve cost effective disease control. The current major foliar diseases to attack barley include powdery mildew (*Blumeria graminis*) rhynchosporium (*Rhynchosporium secalis*), net blotch (*Pyrenophora teres*), brown rust (*Puccinia recondita*) and ramularia (*Ramularia collo cygni*). Some foliar diseases are more sporadic, including yellow rust (*Puccinia striiformis*), whilst other abiotic (non fungal) problems that can attack barley plants include oxidative stress, which is one cause of abiotic leaf spots (Wu & Tiedemann 2002, 2004).

The relative importance of these key diseases changes depending upon varietal resistance, geographical area, local weather conditions and different growth stages. Table 5 shows the disease levels in commercial crops in July taken from surveys funded by Scottish Government (in Scotland) and Crop Monitor (in England).

Table 5 Average disease levels % and maximum disease levels (in brackets) in commercially treated barley crops in July 2004-2008 Scotland and 2004 England.

[Scottish Government data & Crop Monitor data].

Winter barley	England 2004	Scotland 2004	Scotland 2005	Scotland 2006	Scotland 2007	Scotland 2008
rhynchosporium	1.6	1.8 (10)	1 (8)	1.6 (8)	1.9 (10)	0.9 (10)
net blotch	0.8	0.3 (0.5)	0	0.1 (1)	0.1 (3)	0
mildew	0.7	1.8 (2)	1.0 (10)	1.6 (15)	1.9 (2)	0.9 (2)
yellow rust	0	0	0.1 (1)	0	0.1 (1)	0
brown rust	0.2	0.1 (1)	0	0	0.1 (1)	0
Ramularia	0	0	2 (5)	1.1 (8)	0	0
Spring barley	England 2004	Scotland 2004	Scotland 2005	Scotland 2006	Scotland 2007	Scotland 2008
rhynchosporium	-	2.3 (50)	2.6 (10)	1.6 (5)	1.1 (20)	1.9 (5)
net blotch	-	1.4 (2)	0.1 (1)	0	1.6 (5)	0.1 (1)
Mildew	-	0.9 (5)	5.0 (10)	2.3 (10)	0.6 (10)	0.3 (2)
yellow rust	-	0	0	0	0.1 (1)	0
brown rust	-	0.1(1)	0	0	0.6 (1)	0
ramularia	-	35 (70)	0.1 (5)	3 (5)	0	0
No of reports	Unknown	316	273	477	398	209

-No data

Fungicide use and resistance can also influence disease. During the four years of this study, QoI resistance to net blotch increased. Resistance to rhynchosporium was

detected in France in 2008, but it has not been detected in the UK. This will be an issue to look out for in future years.

Table 6 shows details of the current status and potential future risk of fungicide resistance for the fungicides used in this study.

Table 6 Fungicide list by mode of action, active ingredient and trade name

Trade name – active ingredient	Active ingredient	FRAC Group Name	FRAC group name (Short version for report)
Torch extra	spiroxamine	Amine SBI class 11	Amine
Corbel	fenpropimorph	Amine SBI class 11	Amine
Kayak	cyprodinil	Anilino Pyrimidine (AP)	AP
Unix	cyprodinil	Anilino Pyrimidine (AP)	AP
Flexity	metrafenone	Benzophenone	Benzophenone
Bravo	chlorothalonil	Chloronitrile	Chloronitrile
Opus	epoxiconazole	Demethylation inhibitor (DMI)	DMI
Proline	prothioconazole	Demethylation inhibitor (DMI)	DMI
Tracker	epoxiconazole + boscalid	Demethylation inhibitor (DMI) + Succinate dehydrogenase Inhibitor	DMI + SDHI
HGCAB2	experimental fungicide	EXP	EXP
HGCA B1	experimental fungicide	EXP	EXP
Cyflamid	cyflufenamid	Phenyl acetamine	Phenyl acetamine
Talius	proquinazid	Quinazolinone	Quinazolinone
Talius + Corbel	Proquinazid + fenpropimorph	Quinazolinone + Amine SBI class 11	Quinazolinone + Amine
Fortress	quinoxyfen	Quinoline	Quinoline
Amistar	azoxystrobin	Quinone outside Inhibitor (QoI)	QoI
Comet	pyraclostrobin	Quinone outside Inhibitor (QoI)	QoI
Galileo	picoxystrobin	Quinone outside Inhibitor (QoI)	QoI
Twist SC	trifloxystrobin	Quinone outside Inhibitor (QoI)	QoI
Fandango	fluoxastrobin + prothioconazole	Quinone outside Inhibitor (QoI) + Demethylation inhibitor (DMI)	QoI + DMI

The information in Table 6 is based on fungicide list compiled by Fungicide Resistance Action Committee (FRAC)

Variety resistance can also influence the severity of specific diseases (Tables 7 & 8). The introduction of the mlo resistance gene into many spring barley breeding programmes resulted in more spring barley varieties with good varietal resistance. This has little influence on mildew levels seen in commercial crops however, since the current popular malting spring barley variety Optic, does not have this gene.

Table 7 Winter barley variety resistance ratings

Variety	Rhyncho sporium	Mildew	Yellow rust	Brown rust	Net blotch
Wintmalt	6	5	2	6	8
Flagon	8	7	8	7	6
Cassata	8	4	2	7	5
Pearl	7	6	6	6	5
Retriever	8	5	8	6	7
Saffron	6	3	7	7	8
Accrue	8	6	7	7	8
Suzuka	9	5	8	7	7
Camion	6	5	7	5	8
Carat	7	6	7	5	6
Volume	8	5	6	5	8
Bronx	8	7	7	4	8
Pelican	8	7	5	8	6
Colibri	7	8	8	7	8
Boost	8	7	8	4	8
Amarena	8	8	5	8	7
Sequel	8	5	7	5	7

1-9 scale where higher number represents better disease resistance. (9 = best resistance).

[] rating based on limited data

- no information

Ratings in Table 7 and 8 derived from the HGCA Recommended List.

**Ramularia scores based on SAC assessments of Recommended List trials in Scotland.*

Table 8 Spring barley variety resistance ratings

Variety	Rhynchosporium	Mildew	Yellow rust	Brown rust	Ramularia*
Quench	8	9	4	4	6
Cropton	6	9	-	5	6
Concerto	4	9	-	6	5
Publican	8	8	3	5	6
NFC-Tipple	4	8	3	8	7
Forensic	5	5	-	5	6
Belgravia	7	9	[7]	6	7
Westminster	8	9	6	6	7
Cocktail	6	7	4	8	5
Oxbridge	7	7	5	6	5
Cellar	4	9	4	7	5
Optic	4	5	8	6	4
Decanter	6	9	8	5	7
Waggon	3	9	6	5	7
Sweeney	5	9	[4]	8	6
Scout	5	8	[2]	6	7
Jolika	5	9	[5]	4	5
Rebecca	8	6	4	6	7
Doyen	7	7	3	7	6
Riviera	5	8	6	4	5

1-9 scale where higher number represents better disease resistance. (9 = best resistance).

[] rating based on limited data

- no information

Ratings in Table 7 and 8 derived from the HGCA Recommended List.

**Ramularia scores based on SAC assessments of Recommended List trials in Scotland.*

Cost-effective disease control requires good use of varietal resistance, knowledge of diseases and their severity in different regions, knowledge about fungicide activity at different doses in eradication and protectant situations, and the impact of resistant or less sensitive strains of pathogens on disease control. The main aim of this project is to measure and compare the efficacy of fungicides when used under high disease pressure in field situations.

To achieve this aim, field sites and varieties were selected to provide high disease pressure situations in order to put fungicides under a severe test. Fungicides were also applied just once to a crop at different doses. This approach allows the maximum amount of information to be gained on the protectant activity, eradicant activity, yield benefits and impact on green leaf area. This approach is, however, different to that taken by growers who would use fungicides in mixtures, at two or more growth stage

timings. Where a disease is less common in a region, or where more resistant varieties are grown, the control achieved by some of the fungicides used in this research is likely to be improved.

Obtaining information on the current field activity of fungicides is of immediate importance to advisers and growers, since varietal resistance, fungicide resistance and the fungicide products available to growers can all change quickly. As such, it is important that information from this research is disseminated quickly and also any changes in efficacy, which may be a result of changes in resistance. To achieve these aims, a web site was developed to allow scientific contributors to the research access to the data and results. Another web site has also been developed to allow more direct access to the fungicide dose response curves generated by this research.

Materials and methods

Field trials

Over the four years of trials, a total of 24 winter barley trials were carried out throughout the UK. Eight additional spring barley trials were carried out by TEAGASC and SAC to obtain data on ramularia and barley leaf spots.

The number of trials for each target disease in this four year study is listed in Table 9.

Table 9 Number of trials targeting specific diseases

Target disease	Barley sites year 1	Barley sites year 2	Barley sites year 3	Barley sites year 4
powdery mildew	1	1	1	1
rhynchosporium	2	2	2	2
net blotch	2	2	2	2
brown rust ramularia (S barley)	1 2	1 2	1 2	1 2
Totals	8	8	8	8

Sites and cultivars for the experiments were selected to maximise the severity of the target disease. (Table 10).

Table 10 Region, varieties, target disease and treatment timing of field trials

Trial code	Region	Variety	Target disease	Treatment growth stage (GS)	Spray date
501	Lockerbie	Sumo	Rhynchosporium	37	05/05/05
502	Bush, Midlothian	Regina	Powdery mildew	32-33	04/05/05
503	Cornwall	Sumo	Rhynchosporium	32-33	29/04/05
504	Terrington	Pearl	Net blotch	45-49	11/05/05
505	East Anglia	Pearl	Net blotch	37-39	05/05/05
506	East Anglia	Vanessa	Brown rust	37-39	05/05/05
507 508	Bush Carlow	Prestige Pewter	Ramularia Ramularia	60-61 57-59	28/06/05 22/06/05
601	Roberthill Lockerbie	Saffron	Rhynchosporium	37	10/05/06
602	Low Fulford, Midlothian	Cannock	Powdery mildew	32	11/05/06
603	Cornwall	Haka	Rhynchosporium	32-37	03/05/06
604	Terrington	Pearl	Net blotch	37-39	05/05/06
605	East Anglia	Pearl	Net blotch	37-39	05/05/06
606	East Anglia	Spectrum	Brown rust	37-39	05/05/06
607	Low Fulford, Midlothian	Prestige	Ramularia	45-49	15/06/07
608	Carlow	Pewter	Ramularia	55	16/06/06
701	Lanark	Saffron	Rhynchosporium	32	26/04/07
702	Bush, Midlothian	Cannock	Powdery mildew	39-41	27/04/07

703	Cornwall	Haka	Rhynchosporium	32-33	20/4/07
704	Terrington	Pearl	Net blotch	37-39	30/04/07
705	East Anglia	Pearl	Net blotch	39	25/04/07
706	East Anglia	Spectrum	Brown rust	37-39	25/04/07
707	March Park, Midlothian	Prestige	Ramularia	49	11/06/07
708	Carlow	Pewter	Ramularia	49	05/06/07
801	Drumalbin, Lanark	Saffron	Rhynchosporium	32	05/05/08
802	Bush, Midlothian	Camion	Powdery mildew	37-39	07/05/08
803	Cornwall	Saffron	Rhynchosporium	37-39	23/04/08
804	West Ashby, Terrington	Pearl	Net blotch	37-39	06/05/08
805	East Anglia	Pearl	Net blotch	37-39	07/05/08
806	East Anglia	Boost	Brown rust	37-39	06/05/08
807	Hayknowes, Midlothian	Prestige	Ramularia	45-49	23/06/08
808	Carlow	Pewter	Ramularia	55	13/06/08

A detailed protocol (see Appendix 1) was developed providing details of the trial layout, fungicide treatments, disease assessments and site details. An untreated control, a prothioconazole (Proline) standard and an epoxiconazole (Opus) fungicide standard were common in all trials. Not all fungicides were tested in the four seasons and many were not present in all the trials. The statistical methods used to analyses the data took this into account.

Each test fungicide was evaluated at a single timing at four doses (0.25, 0.50, 1.00 and 2.00 times the manufacturer's full recommended dose rate specified for barley) to enable a dose-response curve to be fitted (Table 11). A maximum of eight fungicides were included in each experiment. Treatments were replicated three times, in randomised complete blocks.

Table 11 Fungicides and doses used in field trials

New code	Active ingredient	Product	Rate product/ha	£/ha
1	Epoxiconazole	Opus	2.00 litre	52
2	Epoxiconazole	Opus	1.00 litre	26
3	Epoxiconazole	Opus	0.50 litre	13
4	Epoxiconazole	Opus	0.25 litre	6.5
5	Fenpropimorph	Corbel	2.00 litre	50
6	Fenpropimorph	Corbel	1.00 litre	25
7	Fenpropimorph	Corbel	0.50 litre	12.5
8	Fenpropimorph	Corbel	0.25 litre	6.25
9	Cyprodinil	Unix	1.34 kg	44
10	Cyprodinil	Unix	0.67kg	22
11	Cyprodinil	Unix	0.335 kg	11
12	Cyprodinil	Unix	0.168 kg	5.5
13	Trifloxystrobin	Twist EC	4.00 litre	64
14	Trifloxystrobin	Twist EC	2.00 litre	32
15	Trifloxystrobin	Twist EC	1.00 litre	16
16	Trifloxystrobin	Twist EC	0.50 litre	8
17	Picoxystrobin	Acanto	2.00 litre	56
18	Picoxystrobin	Acanto	1.00 litre	28
19	Picoxystrobin	Acanto	0.50 litre	14
20	Picoxystrobin	Acanto	0.25 litre	7
21	Pyraclostrobin	Comet 200	2.50 litre	56
22	Pyraclostrobin	Comet 200	1.25 litre	28
23	Pyraclostrobin	Comet 200	0.625 litre	14
24	Pyraclostrobin	Comet 200	0.3125litre	7
25	Prothioconazole	Proline	1.60 litre	60
26	Prothioconazole	Proline	0.80 litre	30
27	Prothioconazole	Proline	0.40 litre	15
28	Prothioconazole	Proline	0.20 litre	7.5
29	HGCA4 prothioconazole + fluoxastrobin	UK958 (Fandango)	2.50 litres	62
30	HGCA4 prothioconazole + fluoxastrobin	UK958 (Fandango)	1.25 litres	31
31	HGCA4 prothioconazole + fluoxastrobin	UK958 (Fandango)	0.625 litre	15.5
32	HGCA4 prothioconazole + fluoxastrobin	UK958 (Fandango)	0.3125 litres	7.75
33	Untreated	---	---	0
34	Untreated	---	---	0
35	Untreated	----	---	0
36	Untreated	----	---	0
37	Quinoxyfen	Fortress	0.60 litre	32
38	Quinoxyfen	Fortress	0.30 litre	16
39	Quinoxyfen	Fortress	0.15 litre	8
40	Quinoxyfen	Fortress	0.075 litre	4

Table 11 (continued) Fungicides and doses used in field trials

New code	Active ingredient	Product	Rate product/ha	£/ha
41	Spiroxamine	Neon	3.00 litre	44
42	Spiroxamine	Neon	1.50 litre	22
43	Spiroxamine	Neon	0.75 litre	11
44	Spiroxamine	Neon	0.375 litre	5.5
45	Azoxystrobin	Amistar	2.00 litre	54
46	Azoxystrobin	Amistar	1.00 litre	27
47	Azoxystrobin	Amistar	0.50 litre	13.5
48	Azoxystrobin	Amistar	0.25 litre	6.75
49	HGCA5	Flexity + Corbel	1.0 + 1.08 litres	60
50	HGCA5	Flexity + Corbel	0.5 + 0.54 litres	30
51	HGCA5	Flexity + Corbel	0.25 +.27 litres	15
52	HGCA5	Flexity + Corbel	0.125 + 0.135 litres	7.5
53	Trifloxystrobin	Twist SC (Swift)	1.0	64
54	Trifloxystrobin	Twist SC(Swift)	0.5	32
55	Trifloxystrobin	Twist SC(Swift)	0.25	16
56	Trifloxystrobin	Twist SC(Swift)	0.125	8
57	Chlorothalonil	Bravo 500	4.0 litre	16
58	Chlorothalonil	Bravo 500	2.0 litre	8
59	Chlorothalonil	Bravo 500	1.0 litre	4
60	Chlorothalonil	Bravo 500	0.5 litre	2
61	HGCA6	BAS564	3.0 litres	40
62	HGCA6	BAS564	1.5 litres	20
63	HGCA6	BAS564	0.75 litre	10
64	HGCA6	BAS564	0.375 litres	5
65	HGCA8 (Tracker)	BAS549	3.0 litres	56
66	HGCA8 (Tracker)	BAS549	1.5 litres	28
67	HGCA8 (Tracker)	BAS549	0.75 litre	14
68	HGCA8 (Tracker)	BAS549	0.375 litres	7
69	HGCA10	Talius + Corbel	0.5 + 0.25	48
70	HGCA10	Talius + Corbel	0.25 + 0.25	24
71	HGCA10	Talius + Corbel	0.125 + 0.25	12
72	HGCA10	Talius + Corbel	0.0625 + 0.25	6
73	Flexity	Metrafenone	1.0 litre	36
74	Flexity	Metrafenone	0.5 litre	18
75	Flexity	Metrafenone	0.25 litre	9
76	Flexity	Metrafenone	0.125 litre	4.5
77	Cyflamid	Cyflufenamid	1.00 litre	56
78	Cyflamid	Cyflufenamid	0.50 litre	28
79	Cyflamid	Cyflufenamid	0.25 litre	14
80	Cyflamid	Cyflufenamid	0.125 litre	7

Table 11 (continued) Fungicides and doses used in field trials

New code	Active ingredient	Product	Rate product/ha	£/ha
81	Spiroxamine	Torch extra	1.8 litre	44
82	Spiroxamine	Torch extra	0.9 litre	22
83	Spiroxamine	Torch extra	0.45 litre	11
84	Spiroxamine	Torch extra	0.225 litre	5.5
85	Cyprodinil	HGCA11 (Unix chip)	3.0 litre	30
86	Cyprodinil	HGCA11 (Unix chip)	1.5 litre	15
87	Cyprodinil	HGCA11 (Unix chip)	0.75 litre	7.5
88	Cyprodinil	HGCA11 (Unix chip)	0.375 litre	3.75
89	Proquinazid	Talius	0.50 litre	35
90	Proquinazid	Talius	0.25 litre	17.5
91	Proquinazid	Talius	0.125 litre	8.8
92	Proquinazid	Talius	0.0625 litre	4.4
93	Experimental	HGCAB1	4.0 litre	80
94	Experimental	HGCAB1	2.0 litre	40
95	Experimental	HGCAB1	1.0 litre	20
96	Experimental	HGCAB1	0.5 litre	10
97	Experimental	HGCAB2	2.0 litre	70
98	Experimental	HGCAB2	1.0 litre	35
99	Experimental	HGCAB2	0.5 litre	17.5
100	Experimental	HGCAB2	0.25 litre	8.75

Fungicide costs (£/ha) were based on 2008 season prices. For experimental products, where no commercial price was available, the price was based around equivalent products currently on the market, or given a premium price over currently available fungicides.

The timing of the single fungicide application was determined according to pathogen development. For rhynchosporium and powdery mildew, the target timing was GS32. Brown rust, net blotch and ramularia are diseases characterised by very rapid development during June and July, so the target timing was GS37-39 rather than GS32.

Foliar diseases and percentage green leaf area were assessed visually on 10 tillers per plot on two dates, approximately 3 and 6 weeks after application, to show the maximum extent of disease development and the best estimate of fungicide

performance on each of the upper leaves. In some instances further assessments were done.

All trials were harvested and yielded. Grain moisture and specific weight were determined.

Statistics

This section of the report is divided into four sub-sections viz. Opportunities and Challenges, Data Management, Methodology and Technical Details.

Opportunities and Challenges

In this particular study, overall treatment and trial design were important but easily resolved issues. The greatest challenge was to process the data and to quickly deliver the results in text and graphical forms to the co-ordinator. Yearly summaries were delivered in November of each year, in time for HGCA Roadshow presentations. The cumulative results were produced by the end of December 2005, 2006, 2007 and 2008 for the production of technical notes. In order for the graphical output to be of a standard suitable for use by the co-ordinator, with only minimal further input, a great deal of time and effort was spent in defining requirements and developing Genstat code. Once developed, the programs ran quickly and easily. The emerging requirements caused the programs to continue to be developed throughout the project. This work will continue in the successor project in order to make the programs more robust, easier to use and to satisfy new requirements. The development of a web-based form of result delivery is leading to new statistical and computing challenges.

Data Management

The design for each of the trials was generated by the co-ordinator using standardised EXCEL spreadsheets and then e-mailed to the trial officers. In the course of the trials, data were input, as they were collected. After harvest, the completed spreadsheets were returned by e-mail to the co-ordinator. Each spreadsheet was checked for completeness and then forwarded to the statistician. At the end of each season, the trial spreadsheets used for statistical analysis were loaded onto a dedicated, password protected, web site at BioSS. This arrangement allowed research partners and the HGCA to access the raw data for all the trials. The web site address was www.bioss.ac.uk/afdbarley.

Methodology

The statistical methodology adopted in earlier HGCA funded projects (Paveley, 2000; Wale, 2000) was used. We thank Dr Ainsley (a freelance statistical consultant based in Malton, Yorkshire) for discussions and especially for advice on the fitting of non-linear models to fungicide responses.

Trial Design

The twenty four winter barley trials were designed as randomised block experiments with 3 replicates of 36 treatment combinations (9 fungicides, always including "nothing", by 4 levels - 0.25, 0.50, 1.00 and 2.00 times the label level). For analysis purposes, all levels of the "nothing" fungicide were the same and were untreated controls. Thus the treatment design was 8 fungicides by 4 levels + 4 untreated controls. One of the reasons for having multiple controls in a replicate block was because the curve fitting for each fungicide used the control mean as a common fixed point in the fitting of curves. The fungicides for each trial were selected by the co-ordinator according to the target disease. Over the course of the project new fungicides became available, replacing older products.

The eight spring barley trials were 3 replicates of 6 fungicides by 4 levels + 4 untreated controls - 1 trial only; or 3 replicate of 7 fungicides by 4 levels + 4 untreated controls - 7 trials.

Trial Analysis

For validation purposes, a randomised block analysis of variance was carried out on each disease and green leaf measurement and on the yield and specific weight. The results were e-mailed to the co-ordinator for scrutiny. Protection and eradication variables, for each foliar disease, were defined by averaging over affected leaves of the same assessment. In some trials it proved possible to derive variables for more than one assessment. Green Leaf Area variables parallel to those for disease were also formed. In addition an "Early Green Leaf Area" and a "Late Green Leaf Area" were defined.

In the second stage, the derived variables plus the yield and specific weight were analysed using analysis of variance. Genstat (10th edition for Windows) automatically identified data points with heavy residuals. These were investigated and only when there was sufficient external evidence were the data points excluded. For each

variable, the fungicide by level + untreated control tables were summarised by fitting a non-linear curves for each fungicide and plotting “diagnostic” graphs that showed the fitted line plus data points. Thus unusual behaviour of a fungicide or of individual levels was identified for investigation.

The fungicide by level + untreated control means were written to an EXCEL spreadsheet for subsequent over-trials analysis.

Over-Trial Analysis

At the end of each project year a master EXCEL “data” file for winter barley was assembled from the results from all previous years (i.e. including the results of the previous AFD barley project) plus all the data from the current year.

For winter barley the year’s trials and the accumulated trials from the three previous trial years were summarised at the end of each year. Thus, in 2008 the data were summarised for 2008; for 2007 + 2008; for 2006 + 2007 + 2008; and for 2005 + 2006 + 2007 + 2008.

For spring barley only one summary per year was produced for the current trial year plus the three previous trial years. There were insufficient trials in any year to make annual summaries meaningful.

The financial variables “output” and the “margin” were added using 2008 grain prices. The formulae used were:

Output (£ per ha) = Yield (t/ha)*(150 + 63 - Specific Weight (kg / hl))

Margin over Fungicide (£ per ha) = Output (£ per ha) – Cost of Fungicide (£ per ha)

These formulae take account of both the absolute yield and also changes in quality reflected by the specific weight.

The over-trials analysis produced fungicide by level + untreated control tables for each variable. Curves were fitted to the results and graphs were then produced in the same style as from the trial analysis. All graphs were carefully scrutinised.

Fungicides were compared by multi-line graphs (without the data points). For scientific audiences, they were produced for the full range of levels (0 – 2 label level) and for farming audiences with levels limited to the permissible range (0-1 label level).

The Tables given in this report are mainly of the results at 0.5 label level. The subscript system has been used to compare fungicides statistically.

Technical Details

Trial Analysis

The data were analysed using standard analysis of variance techniques.

Over-Trials Analysis

For all variables, trial means were used for analysis. Disease and Green Leaf variables were then transformed (see later). The tables from the analysis for these variables were back-transformed for reporting purposes.

A mixed model was fitted to the data using the Residual Maximum Likelihood (REML) model fitting in Genstat.

Winter Barley

For the disease and green leaf variables, only a subset of the trials was available and so a simple model was fitted to the data with trial regarded as a fixed effect. For each disease there was a different subset of trials.

The fixed part of the model (in Genstat notation) was:

trial + (fungicide by level + untreated control)

The random part of the model was simply the residual variation.

For some variables, mainly in the annual analysis, data was available from only one trial (e.g. mildew protection and mildew eradication) and thus no model could be

fitted to the data. Consequently, no statistically based grouping of fungicides was possible.

The yield data were divided by target disease and each part was separately analysed.

Spring Barley

The simple model used for the winter barley was fitted to the data.

Transformations

Disease and green leaf data were transformed for the over trials analysis using an empirical logit that allowed for the possibility of 0% or 100% in the data. The transformation was:

$$\text{Logit}(p) = \log((p + 0.5) / (100 + 0.5 - p))$$

where p is a percentage of the leaf area (disease or green leaf).

The purpose was to improve the additivity of the model and thus the way in which information from trials at very different disease pressures was summarised. This transformation improved the relationship between residuals and fitted values and also the normality of the residuals.

The grouping of fungicides was done on the transformed means (see below). For reporting purposes the tables of means were back transformed to the original scale.

Grouping of means at 0.5 label level

Fungicides were formally compared at 0.5 label level. The usual method of indicating the precision of tabular means is to quote a standard error of a difference (almost always an average) and to use this standard error to do Student's t-tests between means. In this particular study, however, there was a wide range in the number of trials for each fungicide and so the average standard error was no longer appropriate. Furthermore, the analysis of the disease and leaf area data was carried out on the transformed scale so tests of significance can only be done on this scale. These problems have been resolved using the following strategy.

It was found possible to directly obtain the standard errors of the differences between each pair of fungicides. This enabled an appropriate t value to be calculated from the difference between the fungicide means and the standard error of this difference. A t-value of more than 2.00 (or less than –2.00) corresponding to a p value of approximately 0.05, was used to determine whether or not a pair of fungicides was statistically different. This test made no allowance for multiple testing. Letters were attached to the means so that fungicides sharing one or more letters were “not statistically different”.

Curve Fitting

The main purpose of fitting curves to the fungicide responses was to summarise graphically the information for each fungicide and thus to allow fungicides to be compared. The curves had the following form:

$y_i(\text{level}) = a_i + b_i * \exp(-k_i * \text{level})$ for fungicide i

For each fungicide there were 4 data points at fungicide levels 0.25, 0.50, 1.00 and 2.00 and also the common untreated control point at fungicide level 0.00 i.e. 5 data points. For the purposes of exposition, previous studies have found that it was desirable that all curves pass through the untreated control point. By re-formulating the curve as:

$y_i(\text{level}) = y_0 + b_i * (1 - \exp(-k_i * \text{level}))$ for fungicide i,

where y_0 is the untreated control, this objective was realised. Thus the number of parameters per fungicide was reduced from three to two. The curves were fitted by non-linear least squares. The parameter k was constrained to lie between 0 and 16. $y_0 + b_i$ was a measure of the asymptotic level of y_i (i.e. at very high levels of fungicide) and k_i a measure of the rate of progress towards the asymptote.

For Margin, a linear correction for the cost of Fungicide was made to the Output curves.

Results

Fungicide activity

To determine a comparison of fungicide activity for each disease, and a measure of changes in efficacy which may have occurred over the four years, data showing disease control at half the Approved label dose for barley were used. This dose is one which can be recognised by growers as being a realistic field rate, and it is also a dose for which there are real values from the field trials. When looking at disease control, it is important to be aware of the disease pressure in the trials. Complete control for a disease where levels in the untreated are very low is an easier task for a fungicide than getting good control in a high disease pressure situation. Table 12 gives a definition of the disease pressure based on the percentage of disease in the untreated controls.

Disease pressures can vary year by year, and it is possible differences in disease control are due more to these differences in pressure than to any change in resistance of a fungicide or group of fungicide. Before any comments can be made concerning potential resistance shifts, additional evidence should be sought to back up these observations from, for example, sensitivity testing of isolates (e.g. evidence of increasing ED50 or ED98 values), or mutations detected through PCR diagnostics.

Table 12 Comments on disease severity in untreated control plots in winter barley, 2005-8.

% Disease	Comment
0-1	Very low
1-5	Low
5-10	Moderate
10-20	High
>20	Very high

Comments in the result tables on the success of the fungicides using definitions indicated in Table 13.

Table 13 Comments on control are based on the following categories in winter barley, 2005-8.

% Control	Comment
0 -25%	Poor control
25-50%	Moderate control
50-75%	Good control
75-100%	Excellent control

Rhynchosporium

Table 14 %Rhynchosporium levels in untreated winter barley, 2005-8.

	%Disease in untreated		
Year	Protection	Eradication	Relative pressure of disease
2005	11.75	23.16	Very High
2006	16.01	26.28	Very High
2007	16.72	14.48	High
2008	12.81	20.36	High
2005-08	14.04	20.68	High

Rhynchosporium levels were high or very high over the four year period (Table 14).

Table 15 %Rhynchosporium (protection) at half label dose in winter barley, 2005-2008.

Fungicide	2005	2006	2007	2008	2005-8	Fungicide type	Comments on protection (2005-08)
Torch extra				12.71	10.83	Amine	Poor
Kayak		6.54	10.59	7.32	7.41	AP	Moderate
Unix	5.62				7.75	AP	Moderate
Flexity				10.09	8.55	Benzophenone	Moderate
Bravo 500	5.59	5.23	9.18	13.23	7.97	Chloronitrile	Moderate
Opus	5.29	6.35	7.94	8.07	6.96	DMI	Moderate
Proline	1.32	1.57	2.81	3.18	2.21	DMI	Excellent
Tracker	3.54	4.89	7.03	8.52	5.85	DMI+SDHI	Good
HGCAB1				5.89	4.59	-	Excellent
Cyflamid				9.77	8.27	Phenyl acetamine	*
Talius				8.46	7.13	Quinazolinone	*
Fortress				9.11	7.70	Quinoline	*
Comet	4.21	5.08	4.24	9.50	5.58	QoI	Good
Galileo	5.66	5.37	7.53		6.91	QoI	Moderate
Fandango	1.30	1.88	3.12	2.45	2.16	QoI+DMI	Excellent
Untreated	11.75	16.01	16.72	12.81	14.04	-	

Strobilurin fungicides gave good to moderate protection against rhynchosporium at half dose (Table 15). Disease pressure was high in all trials, and there is no suggestion that the G143A mutation associated with QoI resistance have been detected in rhynchosporium isolates.

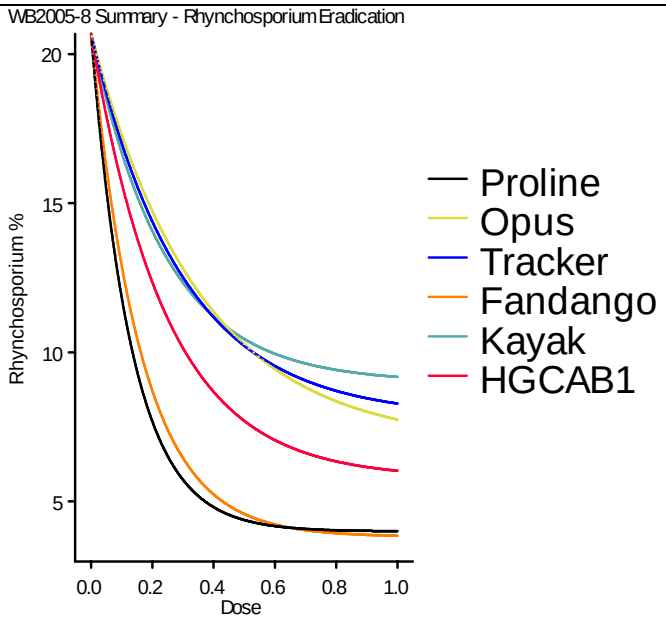
Opus gave consistent protectant activity at these high disease pressure trial sites in the west of the country. Tracker (boscalid & epoxiconazole) gave better protection demonstrating effective protectant activity from the boscalid component. Unix and Kayak also gave moderate protection.

Proline and Fandango gave consistently excellent to good control over the four years. Torch extra gave more variation in their control. This group of fungicides (amines) are recognised to be eradicant fungicides, so the poor persistence may be the reason for this variability in protection.
HGCAB1 was in trial a single season, but it performed well achieving excellent protection against rhynchosporium.

Table 16 %Rhynchosporium (eradication) at half label dose in winter barley, 2005-8.

Fungicide	2005	2006	2007	2008	2005-8	Fungicide type	Comment on eradication
Torch extra				16.90	11.40	Amine	Moderate
Kayak		10.51	5.78	17.38	11.13	AP	Moderate
Unix	12.92				12.77	AP	Moderate
Flexity				10.67	6.96	Benzophenone	*
Bravo 500	17.60	14.89	9.01	27.99	17.13	Chloronitrile	Poor
Opus	14.06	10.80	4.15	16.03	10.78	DMI	Moderate
Proline	5.85	4.70	1.44	12.15	5.46	DMI	Good
Tracker	13.23	12.08	6.23	13.84	11.50	DMI+SDHI	Moderate
HGCAB1				13.75	9.15	-	Good
Cyflamid				10.67	6.96	Phenyl acetamine	*
Talius				12.22	8.05	Quinazolinone	*
Fortress				11.91	7.88	Quinoline	*
Comet	8.02	10.27	5.01	14.97	9.46	QoI	Good
Galileo	13.25	13.93	8.60		14.28	QoI	Moderate
Fandango	6.92	7.32	1.74	7.89	5.60	QoI+DMI	Excellent
Untreated	23.16	26.28	14.48	20.36	20.68	-	

Eradicating rhynchosporium (Table 16) is a greater challenge for fungicides. From Table 16 it can be seen that Fandango achieved the best control, followed by Proline. HGCAB1 also achieved good control. Tracker, Opus and the strobilurin fungicides achieved moderate eradicant activity.



Order of fungicides at full dose

Kayak

Tracker

Opus

HGCAB1

Proline

Fandango

Figure 1 Dose curves for rhynchosporium eradication

Figure 1 shows that Fandango and Proline achieved the best control of rhynchosporium at approximately two thirds dose. HGCAB1 shows reasonable eradicative activity which is intermediate in performance in relation to the best performing fungicides (Proline and Fandango) and Opus, Tracker and Kayak.

Powdery mildew

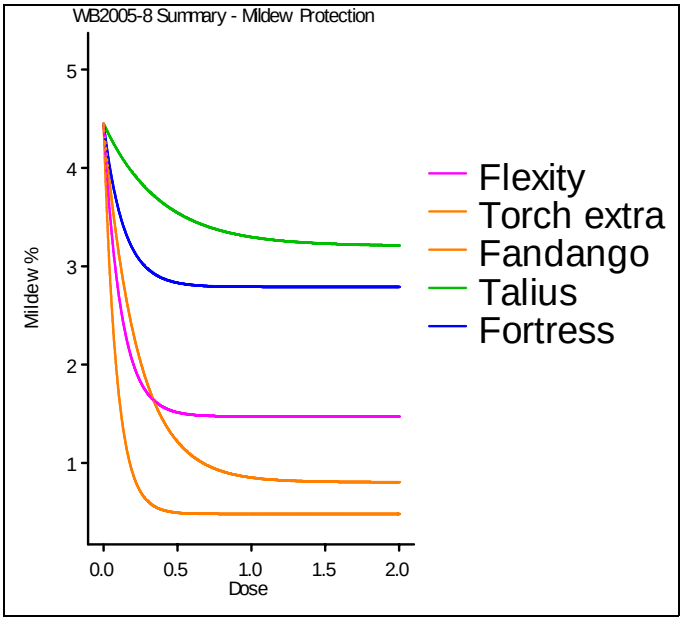
Table 17 %Powdery mildew levels in untreated winter barley, 2005-8.

	%Powdery mildew in untreated		
Year	Protection data	Eradication data	Relative pressure of disease
2005	2.08	3.63	Low
2006	6.79	10.92	High
2007	4.67	8.35	Moderate
2008	5.58	-	None
2005-08	4.45	7.02	Moderate

Disease pressure in powdery mildew was higher in 2006 and 2007 than 2005 and 2008 (Table 17).

Table 18 %Powdery mildew (protection) at half label dose in winter barley, 2005- 2008.

Fungicide	2005	2006	2007	2008	2005-08	Fungicide type	Comment on protection
Torch extra	0.83	1.50	0.23		0.90	Amine	Excellent
Corbel	3.75	2.83	3.00		3.59	Amine	Poor
Kayak				2.50	1.67	AP	Good
Flexity	0.92	0.68	1.33		1.12	Benzophenone	Excellent
Bravo 500				5.67	4.00	Chloronitrile	Poor
Opus	2.00	1.02	1.17	1.33	1.35	DMI	Good
Proline	1.00	1.52	0.37	2.35	1.16	DMI	Good
Tracker				2.67	1.79	DMI+SDHI	Good
HGCAB1				3.83	2.65	-	Moderate
Cyflamid	1.17	3.60	1.17		2.01	Phenyl acetamine	Good
Talius		5.58	1.67		3.51	Quinazolinone	Poor
Fortress	1.08	6.02	1.33		2.49	Quinoline	Moderate
Comet				7.50	5.37	QoI	Poor
Fandango				1.67	1.06	QoI+DMI	Excellent
Untreated	2.08	6.79	4.67	5.58	4.45	-	



Order of fungicides at full dose

Talius

Fortress

Flexity

Fandango

Torch Extra

Figure 2 Dose curves for mildew protection

Flexity, Torch extra, and Fandango gave the best protectant activity (Table 18). The DMI fungicides, Cyflamid and Tracker also achieved good protectant activity. Talius, Comet, Corbel and Bravo 500 achieved poor activity at half dose.

Figure 2 shows the protectant activity of fungicides against mildew Torch extra, Fandango and Flexity achieved the best protection.

Table 19 %Powdery mildew (eradication) at half label dose in winter barley, 2005-2008.

Fungicide	2005	2006	2007	2008	2005-08	Fungicide type	Comment on eradication
Torch extra	6.00	4.17	7.58		5.77	Amine	Poor
Corbel	4.00	8.08	7.67		6.33	Amine	Poor
Flexity	4.50	6.50	6.50		5.76	Benzophenone	Poor
Opus	4.00	4.75	7.67		5.29	DMI	Poor
Proline	4.00	5.00	8.67		5.62	DMI	Poor
Cyflamid	1.50	7.00	6.17		4.18	Phenyl acetamine	Moderate
Talius		11.33	6.00		6.95	Quinazolinone	Poor
Fortress	2.00	12.25	6.33		5.60	Quinoline	Poor
Untreated	3.63	10.92	8.35		7.02	-	

Cyflamid achieved the best eradication of powdery mildew overall.

Brown rust

Table 20 % Brown rust in untreated winter barley, 2005-8.

Year	Protection data	Eradication data	Relative pressure of disease
2005	8.01	3.08	Moderate
2006	-	-	No disease
2007	-	-	No disease
2008	11.38	13.61	High
2005-08	10.44	8.60	Moderate

(- no data)

From Table 20 it can be seen that disease levels were high in 2008 and moderate in 2005. No data was obtained from 2006 or 2007.

Table 21 % Brown rust (protection) at half label dose in winter barley, 2005- 2008.

Fungicide	**2005**	**2006**	**2007**	**2008**	**2005-08**	**Fungicide type**	**Comment on protection**
Torch extra	3.38	-	-	7.50	5.79	Amine	Moderate
Corbel	7.08	-	-		10.20	Amine	Poor
Kayak	-	-	-	10.68	9.50	AP	Poor
Opus	4.71	-	-	4.22	4.33	DMI	Good
Proline	3.46	-	-	4.83	4.45	DMI	Good
Tracker	-	-	-	2.96	2.57	DMI+SDHI	Good
HGCAB1	-	-	-	1.04	0.86	-	Excellent
Amistar	2.83	-	-	6.06	5.05	QoI	Moderate
Comet	2.83	-	-	4.52	4.04	QoI	Good
Galileo	2.08	-	-	4.78	3.68	QoI	Good
Fandango	1.37	-	-	4.03	3.14	QoI+DMI	Good
Untreated	8.01			11.38	10.44	-	

(- no data)

Many fungicides were effective in controlling brown rust (Table 21). The experimental fungicides gave excellent control. Most QoI fungicides achieved good control. Note too Proline gave good control. Kayak is known to be weak against brown rust and gave poor control. Corbel too achieved poor control.

Table 22 %Brown rust (eradication) at half label dose in winter barley, 2005-2008.

Fungicide	2005	2006	2007	2008	2005-08	Fungicide type	Comment on eradication
Torch extra	3.00	-	-	9.24	6.60	Amine	Poor
Corbel	3.33	-	-		7.65	Amine	Poor
Kayak		-	-	16.24	11.36	AP	Poor
Opus	2.67	-	-	9.25	6.26	DMI	Moderate
Proline	1.77	-	-	8.77	5.37	DMI	Moderate
Tracker		-	-	8.17	5.47	DMI+SDHI	Moderate
HGCAB1		-	-	0.97	0.49	-	Excellent
Amistar	1.33	-	-	9.83	5.41	QoI	Moderate
Comet	2.33	-	-	10.00	6.37	QoI	Moderate
Galileo	4.00	-	-	7.93	6.95	QoI	Poor
Fandango	1.67	-	-	7.13	4.55	QoI+DMI	Moderate
Untreated	3.08	-	-	13.61	8.60	-	

(- no data.)

The new experimental fungicide was effective at eradicating brown rust. Most fungicides achieved moderate eradicant activity. The Amines were poor in long term eradicant activity.

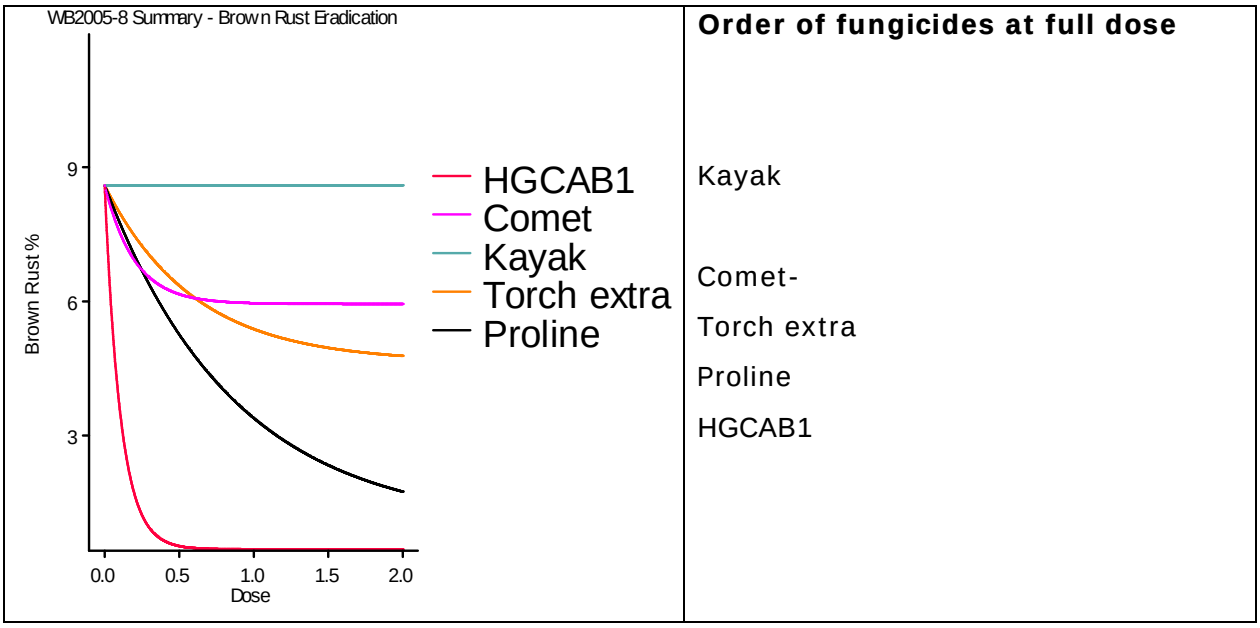


Figure 3 Dose curves for brown rust

QoI fungicides (Comet) continue to give good protection against brown rust. Best control was achieved with the experimental fungicides. Kayak shows poor control of this disease (Figure 3).

Net blotch

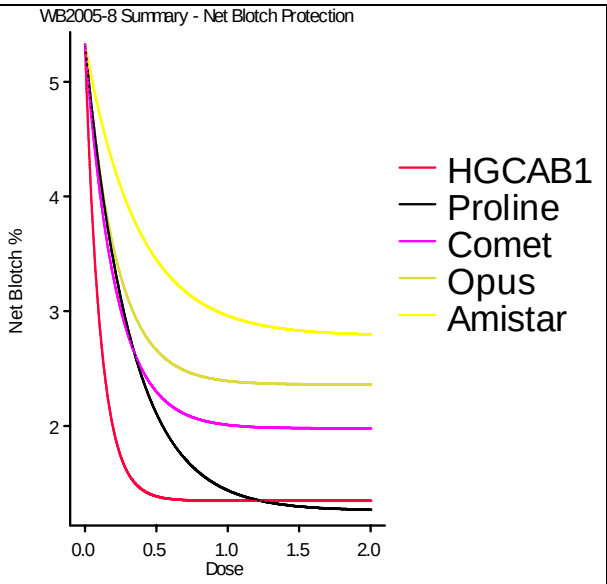
Table 23 % Net blotch levels in untreated winter barley, 2005-8.

	% Net blotch in untreated		
Year	Protection data	Eradication data	Relative pressure of disease
2005	4.56	1.24	Low
2006	8.06	9.59	Moderate
2007	4.60	3.53	Low
2008	4.05	6.17	Moderate
2005-8	5.33	4.06	Low

Disease levels were low to moderate over the four years of testing (see Table 23).

Table 24 % Net blotch (protection) at half label dose in winter barley, 2005–2008.

Fungicide	2005	2006	2007	2008	2005-08	Fungicide type	Comment on protection
Torch extra	-	7.13	6.38	-	5.43	Amine	Poor
Corbel	-	4.20	3.50	-	3.03	Amine	Moderate
Kayak	-	3.94	3.57	2.05	3.30	AP	Moderate
Unix	2.71	-	-	-	2.82	AP	Moderate
Opus	2.85	5.79	2.23	1.39	2.90	DMI	Moderate
Proline	1.65	3.53	0.92	0.75	1.56	DMI	Good
Tracker	3.59	4.63	2.97	0.72	2.74	DMI+SDHI	Moderate
HGCAB1	-	-	-	0.45	1.13	-	Excellent
Amistar	3.34	6.17	3.08	2.09	3.61	QoI	Moderate
Comet	1.47	4.10	2.09	1.29	2.21	QoI	Good
Galileo		4.20	3.34	-	2.96	QoI	Moderate
Twist SC	2.86	5.69	2.00	-	2.86	QoI	Moderate
Fandango	2.22	4.56	1.94	0.84	2.26	QoI+DMI	Moderate
Untreated	4.56	8.06	4.60	4.05	5.33	-	



Order of fungicides at full dose

Amistar

Opus

Comet

HGCAB1

Proline

Figure 4 Dose curves for net blotch protection

The QoI fungicides gave moderate to good control, suggesting no issues in field performance at the trial sites. Proline also achieved good control suggesting this is an effective option where QoI resistance is widespread. The experimental fungicide achieved excellent control based on one year in a moderate disease pressure year. HGCAB1 and Proline achieved the best control of net blotch. (Figure 4). A difference in activity can be seen between the QoI fungicides Comet and Amistar with Comet achieving the better control.

Table 25 %Net blotch (eradication) at half label dose winter barley, 2005-2008.

Fungicide	2005	2006	2007	2008	2005-8	Fungicide type	Comment on eradication
Kayak		8.04	1.10	3.33	2.03	AP	Moderate
Unix	0.50				1.67	AP	*
Opus	1.67	10.22	1.11	3.67	2.55	DMI	Moderate
Proline	0.33	7.58	0.90	4.00	1.79	DMI	Good
Tracker	1.23	9.54	2.31	4.00	3.15	DMI+SDHI	Poor
HGCAB1				3.67	1.93	-	Good
Amistar	2.00	12.98	3.08	4.33	4.16	QoI	Poor
Comet	0.50	6.83	1.55	4.67	2.28	QoI	Moderate
Twist SC	1.57	9.08	2.41		3.65	QoI	Poor
Fandango	0.27	7.79	0.96	4.33	1.84	QoI+DMI	Good
Untreated	1.24	9.59	3.53	6.17	4.06	-	

(- no data. 100% = best eradication)

Table 25 shows that Proline, Fandango and the experimental fungicide achieved the best control. QoI fungicides are now less effective at eradicating net blotch.

Determining significant differences between the fungicides.

Tables 26 and 27 show the average disease present at half dose over three years of trials. This information helps determine significant differences between fungicides. Treatments with the same letter are not significantly different (e.g. fungicide 1 a, fungicide 2 a or fungicide 1 a, fungicide 3 ab). Conversely, where two treatments have a different letter, e.g. fungicide 1 a, fungicide 2 b, they are significantly different. Where the number of trials is high, it can be expected that the differences are more consistent. Care should be taken where the number of treatments is just 1, and in many cases, these values have not been reported.

Note if there was a marked change in the efficacy of a fungicide over the four years, this would be averaged in these tables.

Table 26 %Rhynchosporium (protection and eradication) at half label dose in winter barley, mean 2005-8.

	Protection			Eradication			
Fungicide	**%Disease**	**Sig.**	**No. trials**	**%Disease**	**Sig.**	**No. trials**	**Fungicide type**
Torch extra	10.83	b	1	11.40	aeg	1	Amine
Kayak	7.41	b	6	11.13	cdef	6	AP
Unix	7.75	b	2	12.77	cdef	2	AP
Bravo 500	7.97	b	8	17.13	fg	8	Chloronitrile
Opus	6.96	b	9	10.78	cdef	9	DMI
Proline	2.21	a	9	5.46	a	9	DMI
Tracker	5.85	b	8	11.50	cdef	8	DMI+SDHI
HGCAB1	4.59	b	3	9.15	bcdef	3	-
Comet	5.58	b	8	9.46	cdef	8	QoI
Galileo	6.91	b	6	14.28	cdef	6	QoI
Fandango	2.16	a	8	5.60	ab	8	QoI+DMI
Untreated	14.04		9	20.68		9	-

At half dose, Fandango and Proline achieved the best reduction in disease and gave a significant reduction in disease over the other fungicides (Table 26). Kayak, Opus Tracker, Torch extra, HGCAB1, Comet and Galileo gave the next level of control.

Table 27 %Mildew (protection and eradication) at half label dose in winter barley, mean 2005-8.

	Protection			Eradication			
Fungicide	**% Disease**	**Sig.**	**No. trials**	**% Disease**	**Sig.**	**No. trials**	**Fungicide type**
Torch extra	0.90	a	3	5.77	af	3	Amine
Corbel	3.59	bfgh	3	6.33	ag	3	Amine
Kayak	1.67	af	1	-		-	AP
Flexity	1.12	ac	3	5.76	ae	3	Benzophenone
Bravo 500	4.00	bcfgh	1	-			Chloronitrile
Opus	1.35	ae	4	5.29	ab	3	DMI
Proline	1.16	ad	4	5.62	ad	3	DMI
Tracker	1.79	ag	1	-		-	DMI+SDHI
HGCAB1	2.65	acdf	1	-		-	-
Cyflamid	2.01	agh	3	4.18	a	3	Phenyl acetamine
Talius	3.51	bfgh	2	6.95	bcdefg	2	Quinazolinone
Fortress	2.49	bcdefgh	3	5.60	ac	3	Quinoline
Comet	5.37	fgh	1	-		-	QoI
Fandango	1.06	ab	1	-		-	QoI+DMI
Untreated	4.45		4	7.02		3	-

Torch extra, Kayak, Flexity Opus, Proline, Tracker, HGCAB1, Cyflamid and Fandango achieved the best protection and were significantly better than the other fungicides (Table 27). Comet achieved poor control and this suggests resistance to QoI fungicides is now widespread. For eradication, Cyflamid achieved the best control.

Table 28 %Brown rust (protection and eradication) at half label dose in winter barley, mean 2005-8.

	Protection			Eradication			
Fungicide	% Disease	Sig.	No. trials	% Disease	Sig.	No. trials	Fungicide type
Torch extra	5.79	bi	2	6.60	bd	2	Amine
Corbel	10.20	cdefghi	1	7.65	bf	1	Amine
Kayak	9.50	defghi	2	11.36	cdef	1	AP
Opus	4.33	bf	4	6.26	b	3	DMI
Proline	4.45	bg	4	5.37	b	3	DMI
Tracker	2.57	ab	2	5.47	b	1	DMI+SDHI
HGCAB1	0.86	a	3	0.49	a	2	-
Amistar	5.05	bi	4	5.41	b	3	QoI
Comet	4.04	be	4	6.37	bc	3	QoI
Galileo	3.68	bd	2	6.95	be	2	QoI
Fandango	3.14	bc	4	4.55	ab	3	QoI+DMI
Untreated	10.44		4	8.6		3	-

HGCAB1 shows excellent protectant and eradicant activity (based on a single season). Tracker also gave excellent protection. Corbel and Kayak gave the least protection. Proline achieved similar control of barley brown rust to Opus. (Table 28).

Table 29 %Net blotch (protection and eradication) at half label dose in winter barley, mean 2005-8.

	Protection			Eradication			
Fungicide	% Disease	Sig.	No. trials	% Disease	Sig.	No. trials	Fungicide type
Torch extra	5.43	fghi	2	-			Amine
Corbel	3.03	bcdh	2	-			Amine
Kayak	3.30	cdi	6	2.03	ad	4	AP
Unix	2.82	aef	2	1.67	ab	1	AP
Opus	2.90	cdf	10	2.55	ab	5	DMI
Proline	1.56	ab	10	1.79	a	5	DMI
Tracker	2.74	cde	8	3.15	bcdef	5	DMI+SDHI
HGCAB1	1.13	a	2	1.93	ac	1	-
Amistar	3.61	efghi	10	4.16	c	5	QoI
Comet	2.21	ac	10	2.28	ae	5	QoI
Galileo	2.96	bcdg	2	-			QoI
Twist SC	2.86	cdf	6	3.65	bcf	4	QoI
Fandango	2.26	ad	10	1.84	a	5	QoI+DMI
Untreated	5.33		10	4.06		5	-

(- no data)

HGCAB1 and Proline achieved the best protection, whilst Torch extra was the least effective. Note the differences between Comet and Amistar were significant on disease protection and eradication (Table 29).

Green leaf area retention

Fungicides can also have an influence on the green leaf area retention of the crop. Tables 30 and 31 show green leaf area retention at the four doses (Table 30) and at half dose only with statistical differences shown (Table 31).

Table 30 %Green leaf in winter barley, mean 2005-8.

	Fungicide dose				
Product	0.25	0.5	1.0	2.0	Fungicide type
Torch extra	63.1	63.4	68.2	69.0	Amine
Corbel	53.8	59.5	63.6	67.4	Amine
Kayak	60.8	63.4	62.2	64.5	AP
Unix	51.3	59.2	66.8	70.8	AP
Flexity	61.3	59.8	57.0	59.4	Benzophenone
Bravo 500	62.7	64.4	65.8	72.1	Chloronitrile
Opus	62.2	65.7	72.2	75.6	DMI
Proline	72.6	77.8	84.2	88.8	DMI
Tracker	71.9	74.9	80.2	86.4	DMI+SDHI
HGCAB1	77.8	80.4	82.7	82.5	-
Cyflamid	56.5	55.5	54.5	65.8	Phenyl acetamine
Talius	57.3	59.6	56.2	59.1	Quinazolinone
Fortress	56.4	47.4	55.2	58.2	Quinoline
Amistar	63.6	63.6	66.5	71.9	QoI
Comet	64.1	66.4	69.7	76.8	QoI
Galileo	59.6	62.7	71.7	76.8	QoI
Twist SC	63.3	59.6	65.7	73.2	QoI
Fandango	72.7	80.4	85.0	89.3	QoI+DMI
Untreated	47.8				

The fungicides which achieved the best yields also achieved the best green leaf area retention (e.g. HGCAB1, Fandango, Tracker and Proline.

Table 31 shows the green leaf area levels in order of significance.

Table 31 %Green Leaf at half label dose in winter barley, mean 2005-8.

Fungicide	Leaf	Sig.	No. trials	Fungicide type	
HGCAB1	80.4	a	6	-	**Highest**
Fandango	80.4	a	20	QoI+DMI	
Proline	77.8	a	24	DMI	
Tracker	74.9	b	16	DMI+SDHI	
Comet	66.4	b	20	QoI	
Opus	65.7	b	24	DMI	
Bravo 500	64.4	b	8	Chloronitrile	
Amistar	63.6	b	12	QoI	
Kayak	63.4	b	12	AP	
Torch extra	63.4	b	8	Amine	
Galileo	62.7	b	10	QoI	
Flexity	59.8	bc	4	Benzophenone	
Talius	59.6	bd	3	Quinazolinone	
Twist SC	59.6	be	6	QoI	
Corbel	59.5	bf	6	Amine	
Unix	59.2	bg	4	AP	
Cyflamid	55.5	bh	4	Phenyl acetamine	
Fortress	47.4	cdefgh	4	Quinoline	**Lowest**
Untreated	47.8		24	-	

Yield response to fungicide

Winter barley yields

Yields were recorded in all trials and from these results, the yield response to fungicide was determined for each fungicides. Table 32 provides a definition of the yield responses given in these tables, whilst Tables 33, 34, 35 and 36 shows the fungicide responses relating to the untreated control in each of the four years.

Table 32 Categories for comments on the yield response (t/ha) to fungicide over untreated controls.

Yield response	Comment
-0.25 – 0.00	Negative
0.00-0.25	Slight
0.25-0.50	Moderate
0.50-1.00	High
>1.00	Very High

Table 33 Yield response (t/ha) to fungicides in winter barley, 2005.

	Fungicide dose					
Fungicide	0.25	0.50	1.00	2.00	Yield response	Fungicide type
Torch extra	0.58	0.56	0.94	1.08	High	Amine
Corbel	0.39	0.48	0.77	0.80	Moderate	Amine
Unix	0.48	0.42	0.79	1.22	Moderate	AP
Flexity	0.45	0.54	0.61	0.94	High	Benzophenone
Bravo 500	0.24	0.35	0.68	0.95	Moderate	Chloronitrile
Opus	0.67	1.03	1.16	1.40	Very high	DMI
Proline	1.25	1.38	1.69	1.92	Very high	DMI
Tracker	1.18	1.37	1.37	1.75	Very high	DMI+SDHI
Cyflamid	0.38	0.18	-0.02	0.63	Slight	Phenyl acetamine
Fortress	0.39	0.09	0.47	0.32	Slight	Quinoline
Amistar	0.80	1.10	1.25	1.30	Very high	QoI
Comet	0.80	1.17	1.28	1.64	Very high	QoI
Galileo	0.74	0.69	1.16	1.52	High	QoI
Twist SC	1.00	0.98	1.16	1.16	High	QoI
Fandango	1.03	1.26	1.69	2.07	Very high	QoI+DMI
Untreated	6.08					

In 2005, the best yields were achieved with Fandango, Tracker and Proline at half dose. The majority of fungicides achieved high or moderate yield responses in the 0.25 – 1.0 t/ha category (Table 33).

Table 34 Yield response (t/ha) to fungicides in winter barley, 2006.

	Fungicide dose					
Fungicide	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Torch extra	0.17	0.41	0.72	0.37	Moderate	Amine
Corbel	0.67	0.58	0.61	0.10	High	Amine
Kayak	0.58	0.41	0.66	0.48	Moderate	AP
Flexity	0.72	0.40	0.45	0.22	Moderate	Benzophenone
Bravo 500	0.39	0.41	0.64	0.62	Moderate	Chloronitrile
Opus	0.37	0.44	0.47	0.38	Moderate	DMI
Proline	0.62	0.78	0.95	1.08	High	DMI
Tracker	0.50	0.52	0.98	1.12	High	DMI+SDHI
Cyflamid	0.53	0.85	1.36	-0.05	High	Phenyl acetamine
Talius	0.51	0.90	0.50	-0.26	High	Quinazolinone
Fortress	1.09	0.47	0.81	-0.19	Moderate	Quinoline
Amistar	0.22	0.32	0.38	0.44	Moderate	QoI
Comet	0.51	0.45	0.78	0.67	Moderate	QoI
Galileo	0.37	0.73	0.88	0.81	High	QoI
Twist SC	0.43	0.38	0.70	0.82	Moderate	QoI
Fandango	0.65	0.93	0.92	0.82	High	QoI+DMI
Untreated	7.03					-

In 2006, all fungicides achieved a high or moderate yield response at half dose.(Table 34).

Table 35 Yield response (t/ha) to fungicides in winter barley, 2007.

	Fungicide dose					
Fungicide	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Torch extra	0.04	0.43	0.87	0.57	Moderate	Amine
Corbel	-0.17	-0.34	0.28	0.40	Negative	Amine
Kayak	0.31	0.34	0.42	0.44	Moderate	AP
Flexity	-0.24	-0.20	0.39	-0.08	Negative	Benzophenone
Bravo 500	0.74	0.77	0.85	0.81	High	Chloronitrile
Opus	0.47	0.56	0.88	0.71	High	DMI
Proline	0.64	0.78	1.06	1.33	High	DMI
Tracker	0.38	0.89	0.96	1.14	High	DMI+SDHI
Cyflamid	0.07	-0.30	-0.57	-0.55	Negative	Phenyl acetamine
Talius	-0.57	-0.10	-0.29	-0.85	Negative	Quinazolinone
Fortress	-0.27	-0.17	-0.12	-0.07	Negative	Quinoline
Amistar	0.45	0.56	0.66	1.10	High	QoI
Comet	0.68	0.68	1.02	1.07	High	QoI
Galileo	0.66	0.82	0.98	0.80	High	QoI
Twist SC	0.45	0.45	1.04	0.76	Moderate	QoI
Fandango	0.81	0.99	1.29	1.43	High	QoI+DMI
Untreated	5.35					-

In 2007, negative yield responses were seen with some fungicides. This was predominantly with the mildew specific fungicides (Table 35).

Table 36 Yield response (t/ha) to fungicides in winter barley, 2008.

	Fungicide dose					
Fungicide	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Torch extra	0.09	0.52	0.61	0.44	High	Amine
Kayak	0.24	0.52	0.40	0.38	High	AP
Flexity	0.21	0.35	0.42	0.18	Moderate	Benzophenone
Bravo 500	0.00	0.15	0.45	0.34	Slight	Chloronitrile
Opus	0.55	0.64	0.75	1.04	High	DMI
Proline	0.45	0.97	1.05	1.51	High	DMI
Tracker	0.70	1.01	1.12	1.15	Very high	DMI+SDHI
HGCAB1	0.76	1.03	1.28	1.21	Very high	-
Cyflamid	0.26	-0.30	0.18	0.14	Negative	Phenyl acetamine
Talius	-0.09	-0.22	0.23	0.25	Negative	Quinazolinone
Fortress	0.61	-0.15	0.04	0.01	Negative	Quinoline
Amistar	0.45	0.49	0.85	0.55	Moderate	QoI
Comet	0.56	0.45	0.71	0.91	Moderate	QoI
Galileo	0.19	0.58	0.72	0.61	High	QoI
Fandango	0.91	0.90	1.16	1.09	High	QoI+DMI
Untreated	7.48					-

In 2008, HGCAB1 achieved the best yield at half dose alongside Tracker and Fandango. Mildew specific fungicides achieved negative yield responses, similar to those seen in 2007.

Table 37 Yield response (t/ha) in winter barley, mean 2005-8.

	Fungicide dose					
Product label	0.25	0.5	1.0	2.0	Yield response at half dose	Fungicide type
Torch extra	0.22	0.48	0.79	0.62	Moderate	Amine
Corbel	0.27	0.21	0.52	0.41	Slight	Amine
Kayak	0.49	0.54	0.61	0.55	High	AP
Unix	0.13	0.08	0.45	0.87	Slight	AP
Flexity	0.29	0.27	0.47	0.32	Slight	Benzophenone
Bravo 500	0.34	0.42	0.65	0.68	Slight	Chloronitrile
Opus	0.51	0.67	0.82	0.88	High	DMI
Proline	0.74	0.98	1.19	1.46	High	DMI
Tracker	0.69	0.95	1.11	1.29	High	DMI+SDHI
HGCAB1	0.86	1.12	1.38	1.31	Very high	-
Cyflamid	0.31	0.11	0.24	0.04	Slight	Phenyl acetamine
Talius	0.04	0.28	0.23	-0.20	Slight	Quinazolinone
Fortress	0.46	0.06	0.30	0.02	Slight	Quinoline
Amistar	0.48	0.62	0.79	0.85	High	QoI
Comet	0.63	0.69	0.95	1.07	High	QoI

Galileo	0.53	0.70	0.96	0.98	High	QoI
Twist SC	0.60	0.58	0.94	0.88	High	QoI
Fandango	0.85	1.02	1.26	1.35	Very high	QoI+DMI
Untreated	6.48					

Table 37 summarises the yield responses over the four years for each fungicide.

HGCAB1 (on limited data) and Fandango achieved the best yield overall at half dose. Tracker and the DMI fungicides achieved the next best yields. The strobilurin fungicides continue to achieve high yield responses in barley.

Table 38 Yields (t/ha) at half label dose in winter barley, mean 2005-8.

	Yield	Sig.	No. trials	Fungicide type	
HGCAB1	7.61	a	6	-	**Highest**
Fandango	7.50	a	20	QoI+DMI	
Proline	7.46	a	24	DMI	
Tracker	7.43	ab	16	DMI+SDHI	
Galileo	7.19	bc	10	QoI	
Comet	7.17	c	20	QoI	
Opus	7.15	c	24	DMI	
Amistar	7.10	cd	12	QoI	
Twist SC	7.06	ce	6	QoI	
Kayak	7.02	cf	12	AP	
Torch extra	6.96	cg	8	Amine	
Bravo 500	6.90	ch	8	Chloronitrile	
Talius	6.76	ci	3	Quinazolinone	
Flexity	6.76	defghi	4	Benzophenone	
Corbel	6.70	efghi	6	Amine	
Cyflamid	6.59	ghi	4	Phenyl acetamine	
Unix	6.56	ghi	4	AP	
Fortress	6.55	hi	4	Quinoline	**Lowest**
Untreated	6.48	-	24	-	

- no data

The order of yield response at half dose and the significance is detailed in Table 38.

Table 39 Yields (t/ha) at half label dose where the major disease was rhynchosporium, mildew, brown rust or net blotch in winter barley, mean 2005-08 .

	Rhyncho.			Mildew			Brown Rust			Net Blotch			
Fungicide	Yield	Sig.	Trial No	Yield	Sig.	Trial No	Yield	Sig.	Trial No	Yield	Sig.	Trial No	Fungicide Group
Torch extra				7.39	ad	4	6.59	-	1	6.69	fg	4	Amine
Corbel				7.21	bcde	3	6.45	-	1	6.33	gh	3	Amine
Kayak	7.21	ad	6							6.76	f	6	AP
Unix	6.35	e	2							6.69	fh	2	AP
Flexity				7.07	bd	4							Benzophenone
Bravo 500	6.98	bcd	8										Chloronitrile
Opus	7.25	ad	8	7.60	ac	4	6.88	-	1	6.93	f	12	DMI
Proline	7.54	a	8	7.83	a	4	7.38	-	1	7.28	bd	12	DMI
Tracker	7.40	a	8							7.39	ab	8	DMI+SDHI
HGCAB1	7.34	ab	2	7.71	ab	1				7.74	a	3	-
Cyflamid				6.91	dh	4							Phenyl acetamine
Talius				7.08	bcdf	3							Quinazolinone
Fortress				6.86	efgh	4							Quinoline
Amistar							6.80	-	1	6.94	f	12	QoI
Comet	6.96	bcd	8				7.41	-	1	7.20	bc	12	QoI
Galileo	7.28	ac	6				6.41	-	1	7.02	cdef	2	QoI
Twist SC										6.90	f	6	QoI
Fandango	7.59	a	8				7.19	-	1	7.34	bc	12	QoI+DMI
Untreated	6.61		8	6.78		4	5.74		1	6.30		12	

By segregating trials by the dominant disease (Table 39), it shows that where rhynchosporium is the main disease, Fandango, Tracker, Proline, Kayak, HGCAB1, Galileo and Opus all achieved significantly better yields than the other fungicides.

Where mildew predominates, Torch extra, Opus, Proline and HGCAB1 achieved the best yields. Note the mildew specific fungicides require the addition of a broad spectrum product to achieve the best performance from them.

For net blotch control, HGCAB1 and Tracker achieved the best yields, followed by Fandango, Comet and Proline.

Brown rust was present in one trial, hence no significant differences are available.

Figures 5, 6, 7 and 8 show yields for each of the fungicides following curve fitting. This provides a visual way of understanding the yield response to each of the fungicides.

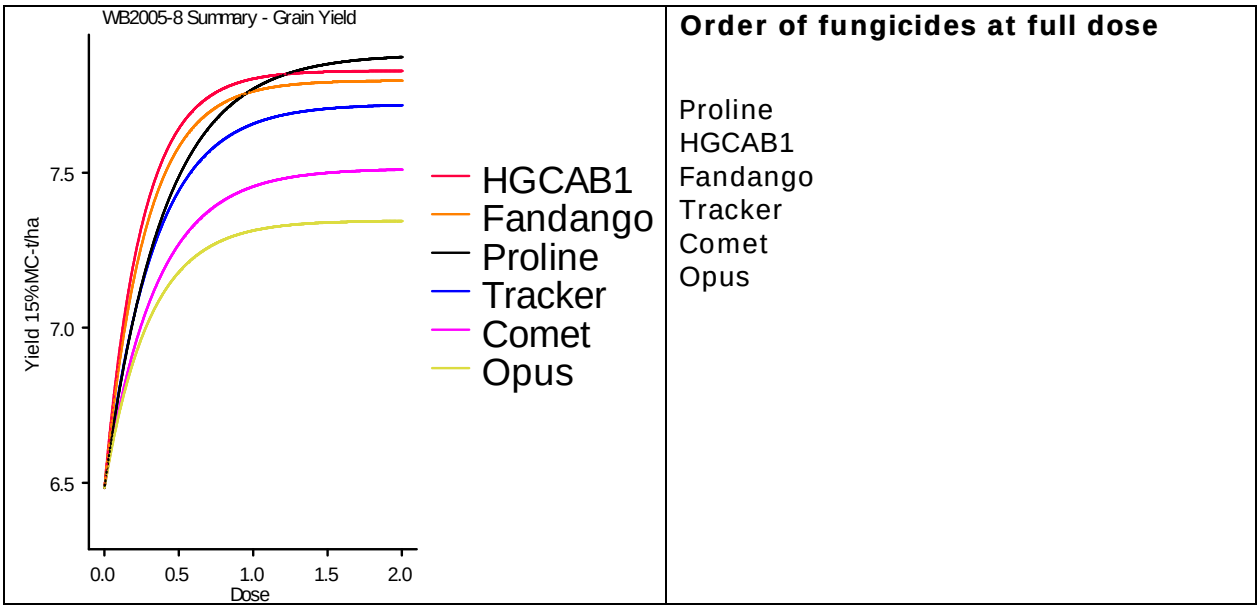


Figure 5 Yield response to fungicides in winter barley

Proline achieved the top yield at full dose in an average of all the trials (Figure 5). HGCAB1 also achieved a similar yield suggesting it has potential to be a good barley fungicide based on an alternative mode of action. Tracker achieves a better yield than Opus (which is one of the components in Tracker).

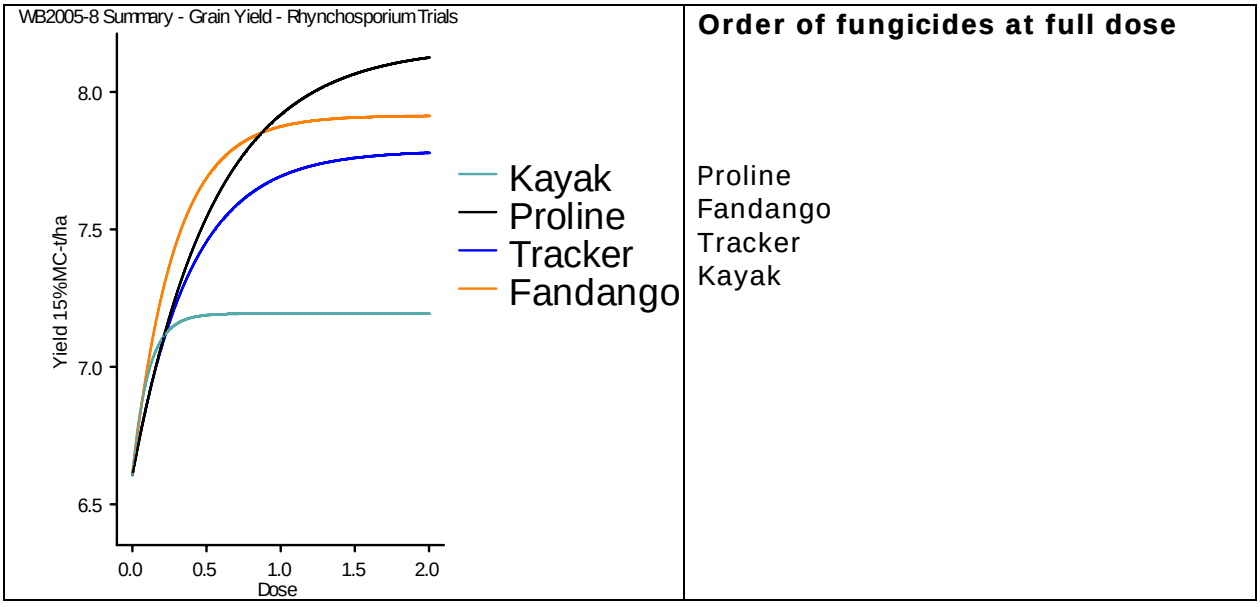


Figure 6 Yield response to fungicides in winter barley in rhynchosporium trials

Focussing on the yields in the rhynchosporium trials, Proline achieved the best yield (Figure 6). Fandango and Tracker also achieved good results.

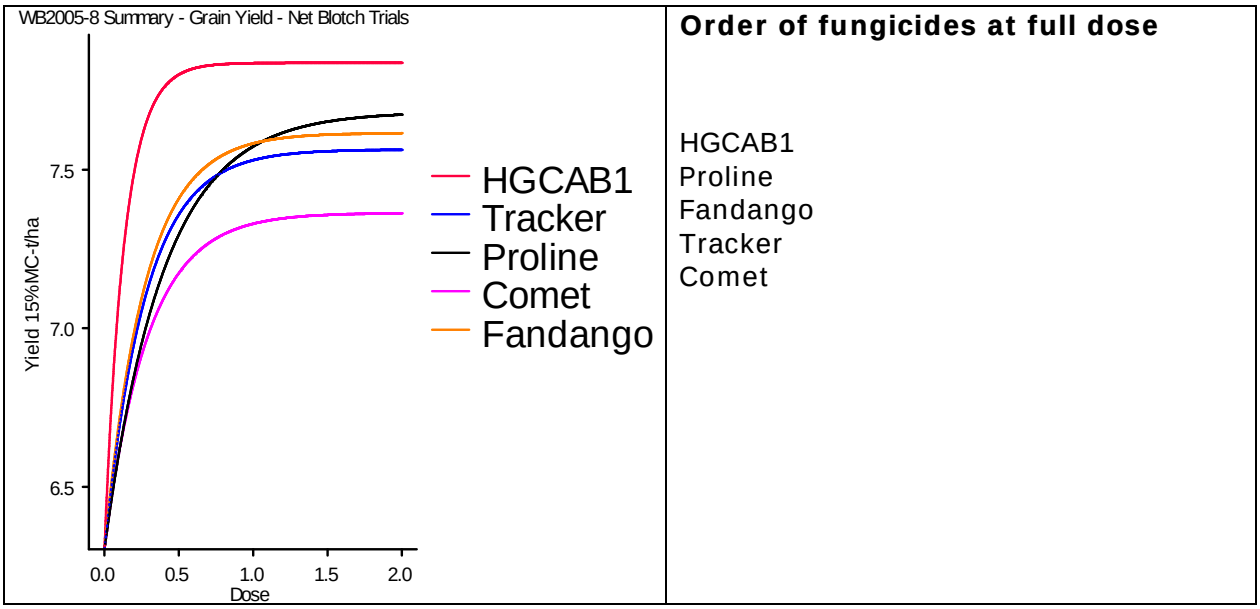


Figure 7 Yield response to fungicides in winter barley in net blotch trials

In the net blotch trials (Figure 7), HGCAB1 achieved the best yield, suggesting this to be one of the strengths of this fungicide.

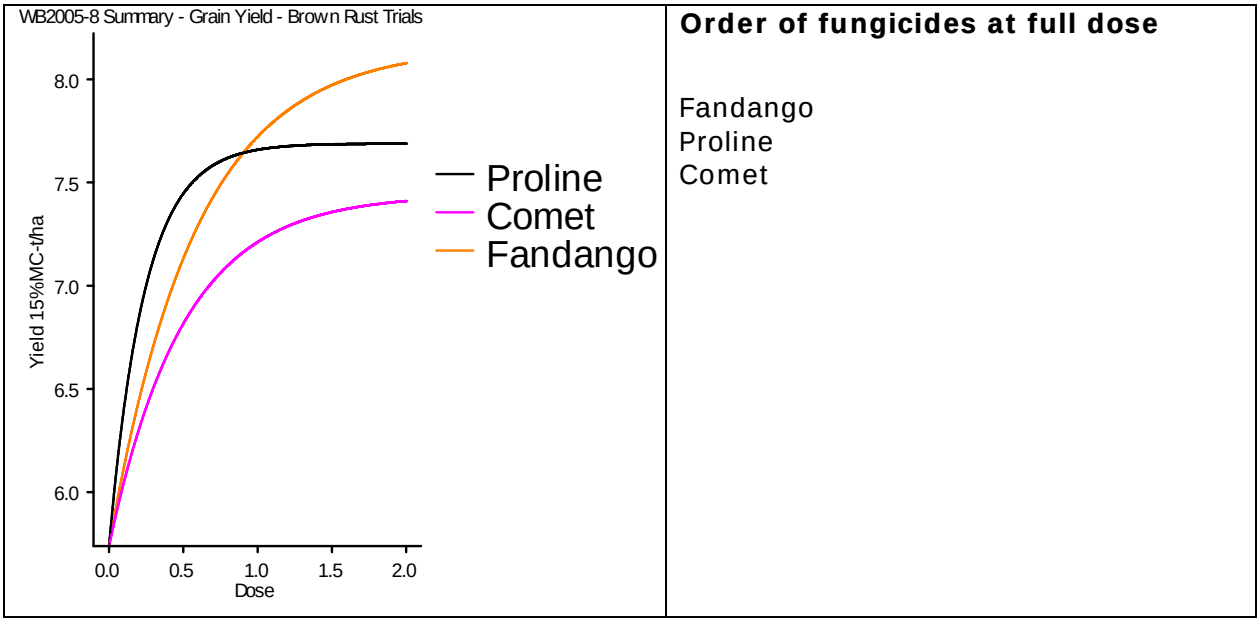
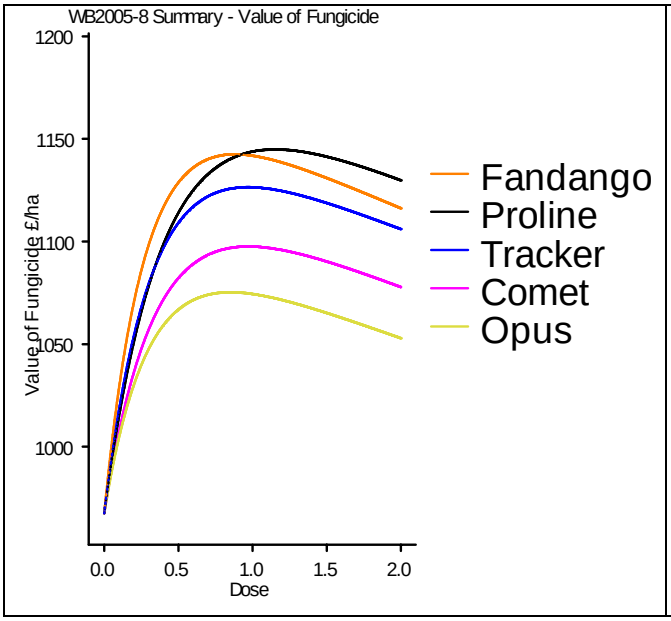


Figure 8 Yield response to fungicides in winter barley in brown rust trials

Figure 8 shows the benefit of the strobilurin component in Fandango over using prothioconazole alone.

Table 40 Margin (£/ha) over fungicide cost at half label dose in winter barley, mean 2005-8.

Fungicide	Margin	Sig.	No. trials	Fungicide type	
HGCAB1	1132	a	6	-	Best value
Fandango	1116	a	20	QoI+DMI	
Proline	1109	a	24	DMI	
Tracker	1106	ab	16	DMI+SDHI	
Galileo	1068	bc	10	QoI	
Comet	1066	c	20	QoI	
Opus	1062	c	24	DMI	
Amistar	1052	cd	12	QoI	
Kayak	1045	ce	12	AP	
Twist SC	1041	cef	6	QoI	
Bravo 500	1035	cf	8	Chloronitrile	
Torch extra	1031	cg	8	Amine	
Talius	1003	ch	3	Quinazolinone	
Flexity	999	degh	4	Benzophenone	
Corbel	987	fgh	6	Amine	
Unix	970	gh	4	AP	
Fortress	968	gh	4	Quinoline	
Cyflamid	967	h	4	Phenyl acetamine	Lowest value
Nil	968		24		



Order of fungicides at full dose

Proline
Fandango
Tracker
Comet
Opus

Figure 9 Value of Fungicides at grain price of £150/tonne

The yield was valued at £150/tonne. Fandango and Proline and Tracker achieved the best value. Table 40 and Figure 9 show the fungicides in order of their value based on yields achieved in the four years of field trials.

Spring Barley

The spring barley trials focussed on ramularia leaf spot disease. Eight spring barley trials were carried out in 2005-2008. Results are reported as a mean of all three sites.

Ramularia

Table 41 Ramularia levels (protection) in untreated spring barley, 2005-8.

Year	%Disease in untreated	Relative pressure of disease
2005	14.70	High
2006	18.47	High
2007	7.65	Moderate
2008	17.29	High
2005-08	13.35	High

Due to the nature of leaf spots, results are for disease protection only (Table 41).

Table 42 %Ramularia (protection) at half label dose in spring barley, 2005-2008.

Fungicide	2005	2006	2007	2008	2005-08	Fungicide type	Comment
Bravo_500	3.77	3.11	2.15	8.20	3.98	Chloronitrile	Good
Opus	9.30	6.44	4.52	6.85	6.61	DMI	Moderate
Proline	4.08	6.22	2.75	7.29	4.62	DMI	Good
Tracker	4.93	5.56	3.20	6.41	4.80	DMI+SDHI	Good
HGCAB2				6.58	5.00	EXP	Good
HGCAB1				6.16	4.67	-	Good
Amistar	12.62	13.11	7.95		11.72	QoI	Poor
Comet	11.29	27.56	7.70		13.06	QoI	Poor
Fandango	4.58	10.67	4.96	5.66	5.65	QoI+DMI	Good
Untreated	14.7	18.47	7.65	17.29	13.35	-	

QoI fungicides were the least effective in controlling ramularia (Table 42). Bravo achieved the best control whilst the triazole fungicides, Tracker and Fandango achieved good control. Note the good activity from the two experimental fungicides.

Abiotic leaf spots (spring barley)

Table 43 Abiotic leaf spots (Protection) in untreated spring barley, 2005-08.

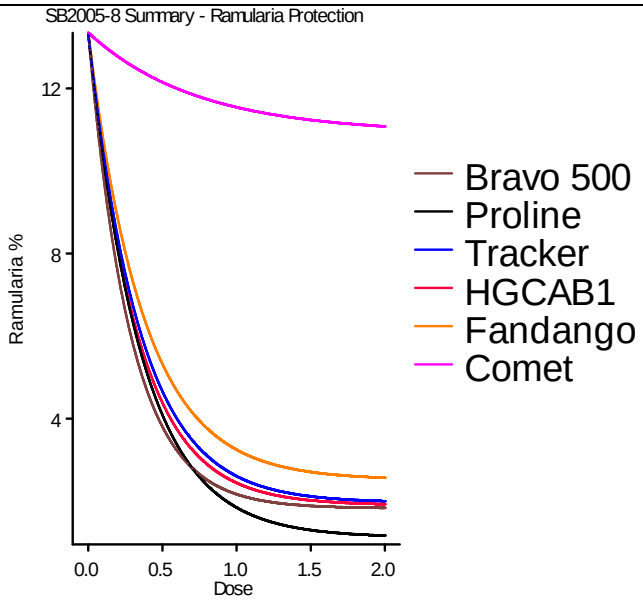
Year	%Disease in untreated	Relative pressure
2005	5.26	Moderate
2006	9.59	Moderate
2007	-	*
2008	14.53	High
2005-08	9.14	Moderate

Results are reported as a mean of all three sites (Table 43). Due to the nature of the development of leaf spots, results are for disease protection only.

Table 44 %Abiotic leaf spots (protection) at half label dose in spring barley, 2005 – 2008.

Product label	2005	2006	2007	2008	2005-08	Fungicide type	Comment
Bravo_500	2.48	6.96		7.74	5.21	Chloronitrile	Moderate
Opus	5.04	3.99		8.90	5.68	DMI	Moderate
Proline	4.95	4.52		6.63	5.30	DMI	Moderate
Tracker	4.20	5.02		7.67	5.48	DMI+SDHI	Moderate
HGCAB2				6.53	4.68	EXP	Moderate
HGCAB1				7.08	5.09	-	Moderate
Amistar	1.41	4.12			3.41	QoI	Good
Comet	4.59	7.33			6.85	QoI	Poor
Fandango	4.84	5.64		6.51	5.63	QoI+DMI	Moderate
Untreated	5.26	9.59		14.53	9.14		

Amistar achieved the best reduction of abiotic leaf spots. Most fungicides achieved moderate control with the exception of Comet (Table 44).



Order of fungicides at double dose

Comet
Fandango
Tracker
HGCAB1
Bravo
Proline

Figure 10 Dose curves for ramularia

Visual representation of control of ramularia can be seen in Figure 10. This shows clearly how ineffective the QoI fungicide Comet is at controlling ramularia.

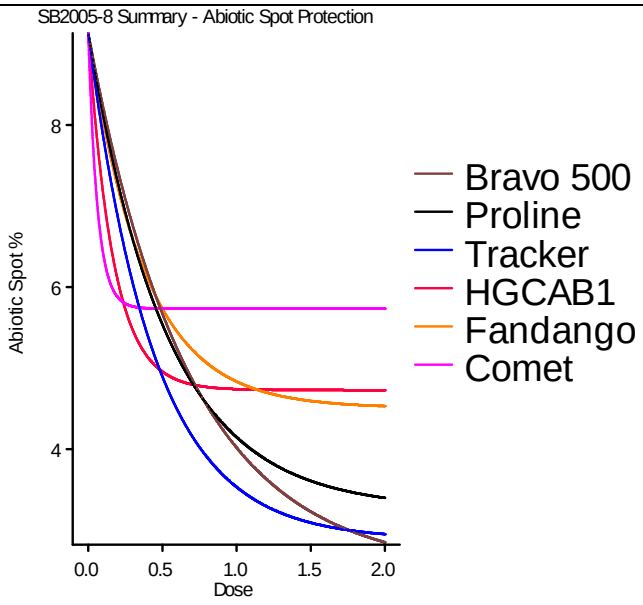
Table 45 %Ramularia and %Abiotic leaf spots (protection) at half label dose in spring barley, 2005-8.

	Ramularia protection			Abiotic protection			
Fungicide	% Disease	Sig.	No. trials	% Disease	Sig.	No. trials	Fungicide Type
Bravo_500	3.98	a	7	5.21	a	6	Chloronitrile
Opus	6.61	ac	7	5.68	a	6	DMI
Proline	4.62	a	7	5.30	a	6	DMI
Tracker	4.80	a	7	5.48	a	6	DMI+SDHI
HGCAB2	5.00	ab	2	4.68	a	2	EXP
HGCAB1	4.67	a	2	5.09	a	2	-
Amistar	11.72	bcd	4	3.41	a	3	QoI
Comet	13.06	d	5	6.85	a	4	QoI
Fandango	5.65	a	7	5.63	a	6	QoI+DMI
Untreated	13.35		7	9.14		7	

Table 45 shows the results for the control of ramularia leaf spot and abiotic leaf spots at half dose only, with statistical differences shown.

Bravo, Proline, Tracker, Opus, Fandango and the two experimental fungicides achieved the best control. The strobilurin fungicides achieved no control. This suggests resistance is now present at close to 100%. All fungicides achieved

significant control of abiotic leaf spots. This shows the strobilurin fungicides continue to have a role in controlling these types of spots.



Order of fungicides at double dose

Comet
HGCAB1
Fandango
Proline
Tracker
Bravo

Figure 11 Dose curves for abiotic spots

Comet continues to provide a reduction in abiotic leaf spots (Figure 11).

Spring barley yields & margins

Table 46. Yield response (t/ha) to fungicides in spring barley, 2005.

	Fungicide dose					
Product label	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Bravo_500	0.10	0.04	0.46	0.47	Slight	Chloronitrile
Opus	0.17	0.28	0.37	0.24	Moderate	DMI
Proline	0.25	0.39	0.15	0.26	Moderate	DMI
Tracker	0.52	0.01	0.55	0.52	Slight	DMI+SDHI
Amistar	0.27	0.24	0.21	0.09	Slight	QoI
Comet	0.00	0.01	0.07	0.20	Slight	QoI
Fandango	0.47	0.21	0.29	0.28	Slight	QoI+DMI
Untreated	6.72					

Table 47. Yield response (t/ha) to fungicides in spring barley, 2006.

	Fungicide dose					
Product label	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Bravo_500	0.28	0.24	0.25	0.38	Slight	Chloronitrile
Opus	0.43	0.68	0.26	0.10	High	DMI
Proline	0.28	0.38	0.60	0.63	Moderate	DMI
Tracker	0.51	0.75	0.55	0.26	High	DMI+SDHI
Amistar	0.16	-0.05	0.32	0.21	Negative	QoI
Comet	0.39	0.55	0.67	0.51	High	QoI
Fandango	0.46	0.50	0.69	0.39	High	QoI+DMI
Untreated	6.83					-

Table 48. Yield response (t/ha) to fungicides in spring barley, 2007.

	Fungicide dose					
Product label	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Bravo_500	0.16	0.12	0.13	0.43	Slight	Chloronitrile
Opus	0.32	0.11	0.35	0.25	Slight	DMI
Proline	0.15	0.43	0.26	0.64	Moderate	DMI
Tracker	0.33	0.42	0.48	0.49	Moderate	DMI+SDHI
Amistar	0.14	0.17	0.37	0.16	Slight	QoI
Comet	0.19	0.15	0.31	0.30	Slight	QoI
Fandango	0.31	0.41	0.61	0.70	Moderate	QoI+DMI
Untreated	6.20					-

Table 49. Yield response (t/ha) to fungicides in spring barley, 2008.

	Fungicide dose					
Fungicide	0.25	0.5	1.0	2.0	Yield response	Fungicide type
Bravo_500	0.08	0.31	0.66	0.79	Moderate	Chloronitrile
Opus	0.11	0.29	0.40	0.40	Moderate	DMI
Proline	0.44	0.51	1.22	1.19	High	DMI
Tracker	0.28	0.43	0.81	0.85	Moderate	DMI+SDHI
HGCAB2	0.13	1.03	0.74	0.85	Very high	EXP
HGCAB1	0.38	0.71	1.09	0.69	High	-
Fandango	0.34	0.86	0.60	1.01	High	QoI+DMI
Untreated	5.69					-

Tables 46, 47, 48 and 49 show the yields in each of the trial years.

Table 50. Yield (t/ha) at half label dose in spring barley, mean 2005-8.

	Yield	Sig.	No. trials	Fungicide	
HGCAB2	7.23	a	2	EXP	**Highest yield**
HGCAB1	6.91	acdef	2	-	
Fandango	6.85	ab	8	QoI+DMI	
Proline	6.78	bc	8	DMI	
Tracker	6.76	bd	8	DMI+SDHI	
Opus	6.70	be	8	DMI	
Comet	6.65	bf	6	QoI	
Bravo 500	6.53	cdef	8	Chloronitrile	
Amistar	6.49	def	5	QoI	**Lowest yield**
Untreated	6.36	-	8	-	

Table 50 and Figure 12 show the yields averaged over the four years. With limited data, the experimental fungicides HGCAB2 and HGCAB1 achieved high yield responses. Of the fungicides currently available on the market, Fandango, Proline, Opus and Tracker achieved effective yields and effective control of ramularia leaf spot. Note Comet despite the poor control of ramularia leaf spot, achieved an effective yield. Conversely, Bravo achieved effective control of ramularia leaf spot, but achieved a lower yield response than would have been expected.

Figure 12 shows the superiority of HGCAB1 and Proline in achieving good yields. Comet did increase the yield, despite poor control of the disease. This suggests that when used as part of a fungicide mixture, it still contributes to the overall yield and quality of the grain.

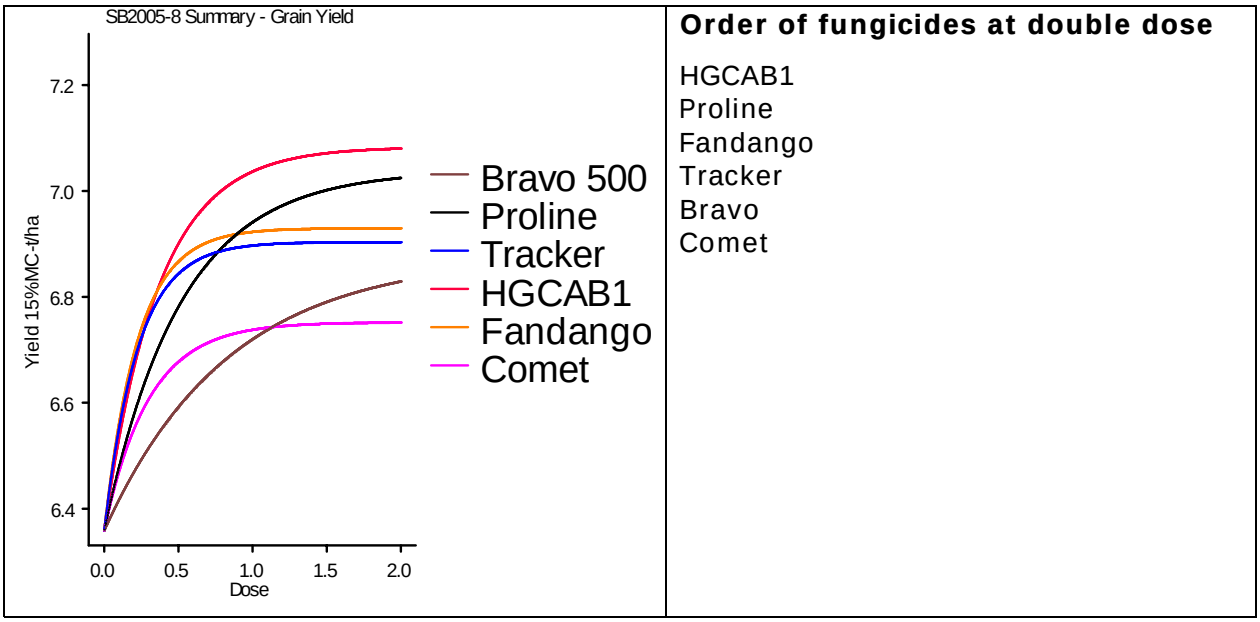


Figure 12 Spring barley yields

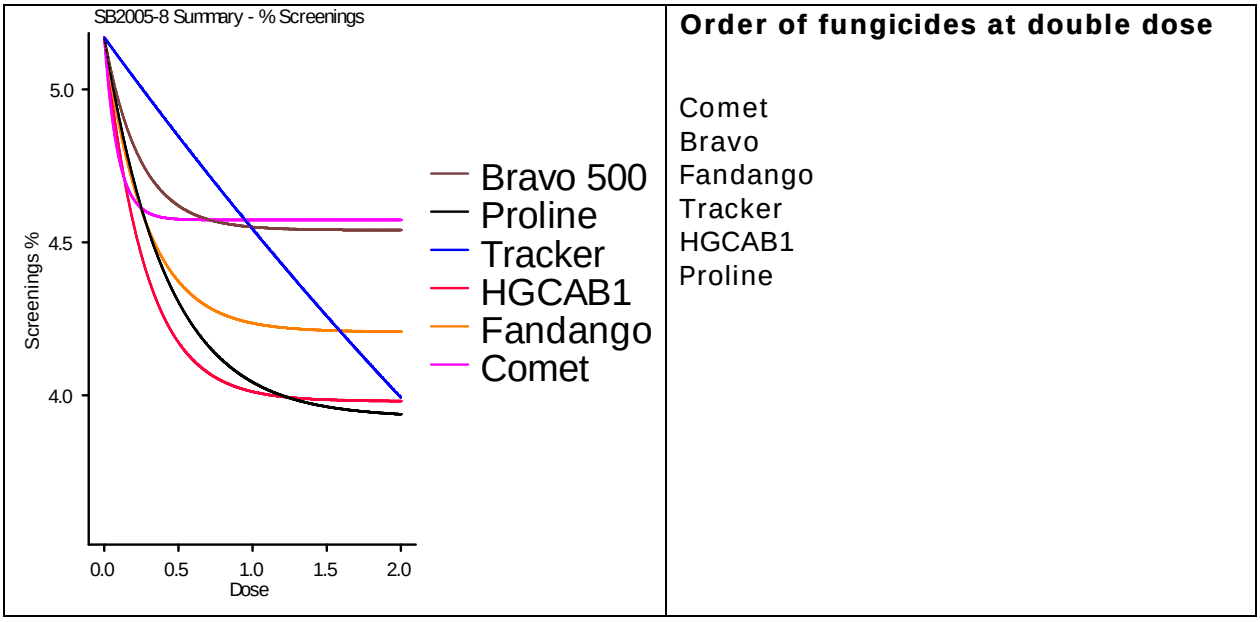
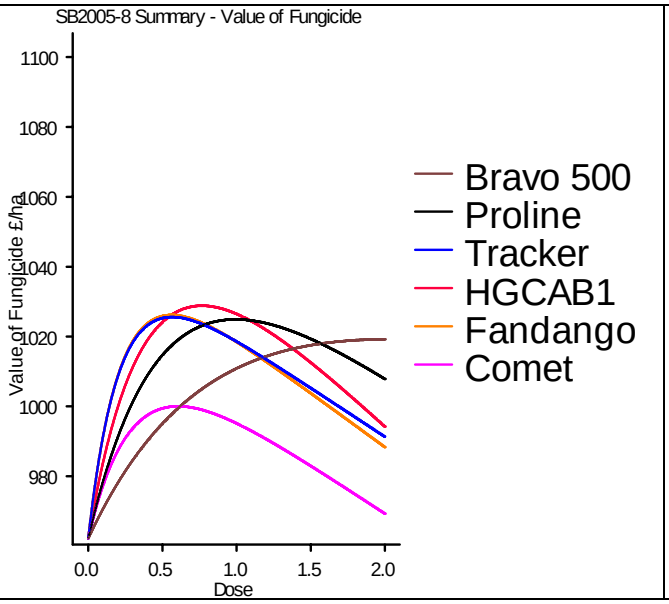


Figure 13 Screenings (2.5 mm sieve) in spring barley trials.

Quality (in the form of screenings) are shown in Figure 13. Comet achieved similar reductions to Bravo. Proline and HGCAB1 achieved the best quality.



Order of fungicides at double dose
Bravo
Proline
HGCAB1
Tracker
Fandango
Comet

Figure 14 Margin over fungicide costs £/ha in winter barley for QoI fungicides

At full dose, Proline, Tracker, Fandango achieved the best margin. Bravo and Comet were lower, but both fungicides can contribute to overall disease control when applied in a mixture (Figure 14).

Spring barley green leaf area

Table 51 %Green leaf area at half label dose in spring barley, mean 2005-8.

Fungicide	Green leaf	Sig.	No. trials	Fungicide type	
HGCAB1	82.1	a	2	-	Highest
HGCAB2	75.5	ab	2	EXP	
Proline	68.9	ac	6	DMI	
Tracker	66.3	ad	6	DMI+SDHI	
Opus	65.0	ae	6	DMI	
Fandango	63.0	bcde	6	QoI+DMI	
Comet	62.5	bcde	4	QoI	
Bravo 500	56.9	bcde	6	Chloronitrile	
Amistar	49.2	de	4	QoI	Lowest
Untreated	38.3	-	6		

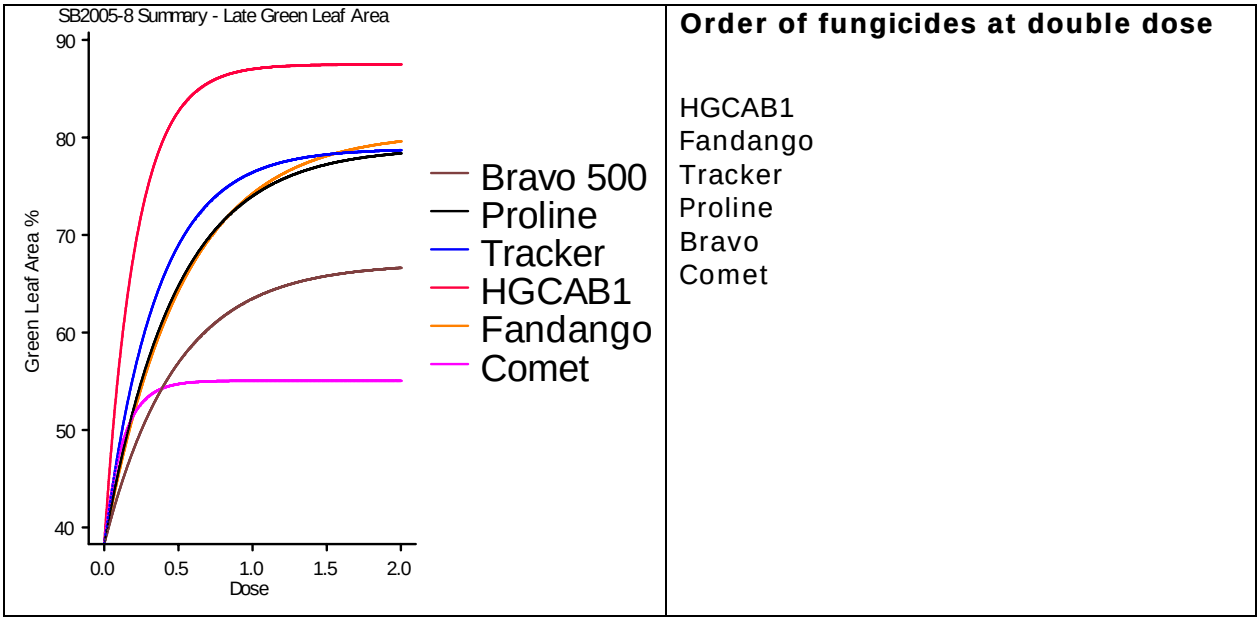


Figure 15 Green leaf area retention in spring barley for co-formulations and standards

The experimental fungicides achieved the best green leaf area retention. Proline, Tracker and Opus also achieved good results. (Table 51 & Figure 15). Bravo and QoI fungicides were less effective at maintaining green leaf area retention when used alone.

Fungicide performance dose curve generator

A summary of curves generated as part of this research can be found in Appendix 2. These curves may be easier to view in an electronic version of this report, since the curves are colour coded. A list of the order of fungicides in each graph is given in Appendix 2 to allow easier interpretation for black and white copies. A method to allow growers to compare the curves for fungicides by disease and years is available *via* the SAC web site at www.sac.ac.uk/crops or *via* links from the HGCA web site.

Barley disease control technical note.

A technical note funded by the Scottish Government was published in May 2009. The note places the appropriate dose work into a broader context of disease management in barley. Colour copies are available *via* the HGCA or at SAC from Publications, SAC, West Mains Road, Edinburgh EH9 3JG. Electronic versions are also available *via* the SAC web site at www.sac.ac.uk/crops.

Discussion

Over the four years of the research, a total of twenty four winter barley trials and eight spring barley trials were undertaken. This provides a full set of data for yields, specific weights and green leaf area.

Yields and margins

A grower will expect to treat crops two or three times with a mixture of fungicides. This research deconstructs a programme into a single component at a single timing. Such an approach should create a level playing field for the comparison of fungicides, but this method is likely to favour broad spectrum fungicides. It is fairer to compare fungicides in the same active group i.e. the QoI fungicides or the DMI fungicides. Knowledge about whether a fungicide can pay for itself in yield increases is important to a grower, who has to make a decision on whether to control a disease or not.

The functional form of curve fitting for margins is different from that of fungicide activity. A typical pattern will have the most cost effective dose somewhere in the middle of the dose range, as opposed to disease control where the best control will be at the highest dose. The margin over fungicide cost is subject to change depending upon the value of the grain and also the cost of the fungicide. Over the four year period, grain prices fluctuated widely from £80/tonne to over £150/tonne. Fungicide prices have also risen, but not to the same extent.

As a general guide, the results on yield and value for money show that the broad spectrum fungicides Proline, Fandango and Tracker are the most cost effective. Fungicides which have a specialised use (i.e. mildew protection) tend to exhibit a smaller yield response and cost benefit in this trial design.

Yield benefits from controlling disease in winter barley were in the region of 1-2 t/ha. This represents a yield penalty of 13-26% based on an average yield of 7.5 t/ha if no effective fungicide had been applied. Having fungicides with broad spectrum activity is also very useful to a grower, since forecasting the dominant disease is challenging. Even in this research where region and variety were selected to favour a specific disease, it was common for other diseases to dominate. For a grower therefore, selecting a broad spectrum fungicide or fungicide mixture which covers several main

diseases is important to ensure best disease control and the consequential yield benefit. There are reasons why the most effective fungicides are not used. Availability has become an issue in recent years, so knowledge of all the fungicides efficacy provides growers with the information to make decisions on the appropriate fungicides to apply in situations where the main fungicides are in short supply.

Rhynchosporium

Disease level was high in the four years of testing. Proline and Fandango were consistently amongst the best fungicides to achieve good protection and eradication. This is good news to growers, since it provides an effective way of managing the disease. The QoI fungicides as a group gave good protectant activity, which makes them a key group to manage rhynchosporium. A close watch on potential resistance changes will be required, since the loss of this group will put a lot of pressure on the new fungicide Proline. Resistance has already started to occur in France, so this research provides a useful baseline of activity to monitor potential drops in activity associated with resistance. Resistance to the DMI fungicide Opus is known to exist, but in the trials in this study, it performed well, giving good protection. This is useful since the same fungicide is a main component of the co-formulated fungicide Tracker. Any change in performance in Opus will potentially lead to a drop in performance in Tracker. Data is limited, but there is a trend towards HGCAB1 showing useful protection against rhynchosporium which is superior to UNIX (epoxiconazole). This will provide an alternative method to manage this disease if existing fungicides should either be withdrawn as a consequence of changes in EU legislation, or changes associated with fungicide resistance.

Powdery mildew

Flexity, Torch extra and Fandango achieved the best protection against powdery mildew. The fungicides Torch extra, Corbel and Cyflamid the best eradication. Talius and Fortress achieved poor protectant activity and at half dose were significantly different to Flexity. The continuing protectant activity from Proline is good news, but it should not be relied upon for sole control of this disease. Achieving a yield response from specific mildew fungicides tends to be low in winter barley.

Brown rust

Brown rust remains relatively straight forward to control with a wide range of fungicides. The QoI fungicides continue to provide effective control as do the DMI

fungicides Opus and Proline. Of the morpholines, Torch extra has better activity than Corbel. The experimental fungicide HGCAB1 achieved excellent control and if the performance seen in 2008 continues, will become a new standard in managing this disease.

Net blotch

Net blotch has increased in recent years. Proline and Comet achieved the best control and a combination of these two fungicides would be the best choice where risk of the disease is high. The other QoI fungicide (Amistar) was weaker in performance than Comet. This suggests that not all fungicides in the same grouping are equally active against the disease. Further analysis of the data is required to determine if this difference in activity has occurred in each season, or only in the latter seasons. The experimental fungicide HGCAB1 achieved effective control in common with the best fungicides currently available to control the disease.

Ramularia and abiotic leaf spots

These trials focussed on spring barley where the disease complex is most severe, but they can also be found on winter barley. The experimental fungicides HGCAB1 and HGCAB2 achieved effective control similar to the current standards Proline, Bravo and Tracker. QoI fungicides are resistant to ramularia, but there are differences in their control of abiotic leaf spots. Amistar shows good activity against these physiological spots. Yield responses to ramularia control did vary, with Bravo being less effective than Proline. The potential for Bravo to be suppressing symptom development as opposed to controlling fungal biomass in the leaf is currently under test in other HGCA funded research.

Green leaf area

As well as controlling disease, fungicides can prolong the green leaf area of barley leaves. The greening effect once associated with QoI fungicides when they were first introduced is no longer as evident where the target disease is resistant to the fungicide (i.e. ramularia). Bravo and Proline are two intriguing fungicides in that both achieve similar greening of leaves, but the yield response where effective disease control has been achieved is different.

Knowledge transfer was a key component of this research. As further years data are available, changes in disease control and potential shifts can be monitored. The

information in this report was made available *via* a Scottish Government funded Technical note which placed the work into a wider context of disease management. Information from this research, including dose curves and star charts are used in the HGCA publication on Barley diseases. A Fungicide Performance Dose Curve Generator has been kept up to date to enable users access to all the curve data. The use of the curves may be best suited to BASIS qualified growers and consultants in understanding the potential impact of cutting fungicides and the impact this has on all diseases, yields and margins. Future developments of the generator will greater flexibility of the research information.

This series of work has immediate benefits to the industry in providing independent information of disease activity, yield response and value for money. It also provides information on the strengths and weaknesses of new fungicides and changes in activity of more established fungicides. Using this information alongside results from molecular studies provides an insight into how changes in pathogen populations associated with fungicide resistance are reflected in field performance.

Acknowledgements

We would like to thank the Agrochemical manufacturers for allowing access to experimental fungicides in advance of gaining Approval in the UK.

We would also like to thank Prof James Burke and Dr Ritchie Hackett, TEAGASC, Carlow, Eire for their contributions to this project.

We would like to thank the field staff at SAC, ADAS and TAG for their contributions in making a success of the field trials.

References

Fountaine, J.M., Fraaije, B.A. (2009) Development of QoI resistant alleles in populations of *Ramularia collo-cygni* (2009) Aspects of Applied biology 92, The second European Ramularia Workshop - A New Disease and challenge in barley production. p123-126.

Paveley ND (2000) Appropriate fungicide doses on winter wheat: research information for growers on the control of powdery mildew, brown rust and Septoria nodorum. Project Report 214. Home-Grown Cereals Authority.

Wale S J (2000) Appropriate fungicide doses for winter barley: evaluation of appropriate fungicide dose programmes. Project Report 215. Home-Grown Cereals Authority.

Wu, Y. X., A. v. Tiedemann, (2002). Evidence for oxidative stress involved in physiological leaf spot formation in winter and spring barley. Phytopathology 92, 145-155.

Wu, Y. X., A. v. Tiedemann, (2004). Light-dependent oxidative stress determines physiological leaf spot formation in barley. Phytopathology 94, 584-592.

Appendix 1 Protocol for field trials

VERSION 1
Crops Division Study Number 00666 (08 series)

Year 7 Trials (Year 4 in second contract)

Study Title: Appropriate Doses network: new fungicide performance information for Barley growers

Name of Sponsors / Contacts: HGCA , Agriculture and Horticulture Development Board, Stoneleigh Park, Kenilworth, Warwickshire, CV8 2TL

Tel: 0247 669 2051

Study Objectives: To keep fungicide dose-response information for HGCA levy payers 'live' and up to date, by quantifying:

- the biological and economic performance of new active ingredients, and
- changes in the dose of established products required to achieve effective control, due to shifts in pathogen sensitivity.

Detailed objectives

To establish an Appropriate Doses Network between the UK, Denmark and Ireland, to provide growers with independent information on dose-response curves for novel fungicides, and allow selection of the most cost effective product/dose combinations for control of the major foliar diseases, in order to maximise margin.

To quantify dose-response curves against each of the major foliar diseases by field experiments in the UK. Comparable data will be made available, on a reciprocal basis, from Denmark and Eire.

To create a password protected central database, linked to the Internet, to allow remote data entry and access by the collaborating countries.

To develop statistical techniques to allow data from different dose and timing treatments to be combined, summarised and tested for significance.

To determine dose-response curves for new and recently-introduced fungicides for the major foliar diseases of winter wheat.

Study Timetable: 1 August 2007 – 31 March 2009
Field work complete 31 October 2008
Final report completion date 31 March 2009

Study status: non regulatory.
QA SAC responsibility

'The study will be conducted within SAC Crops Division Quality Assurance System

Test System: winter or spring barley, 2 x 18 metre plots

Year 6 (2007) Harvest)

Target disease	SAC	ADAS	TAG	TEAGASC	**Total year 4**
Powdery mildew	1 (Site 2)	0	0	0	**1**
Rhynchosporium	1 (Site 1)	1 (site 3)	0	0	**2**
Net blotch	0	1 (Site 4)	1 (Site 5)	0	**2**
Brown rust	0	0	1 (Site 6)	0	**1**
Ramularia	1 (site 7)	0	0	1 (Site8)*	**2**
Totals	**3**	**2**	**2**	**1**	**8**

Trial recognition codes

Target disease	SAC	ADAS	TAG	TEAGASC
Powdery mildew	00666(0802)	0	0	0
Rhynchosporium	00666(0801)	00666(0803)	0	0
Net blotch	0	00666(0804)	00666(0805)	0
Brown rust	0	0	00666(0806)	0
Ramularia	00666(0807)	0	0	00666(0808)
Totals	**3**	**2**	**2**	**1**

To achieve target disease crop may either be winter barley or spring barley.

Each test fungicide will be evaluated at a single timing at four doses (0.25, 0.50, 1.00 and 2.00 x the manufacturer's full recommended rate) to enable a dose-response curve to be fitted.

The timing of the single fungicide application will be determined according to pathogen development.

Rhynchosporium

For rhynchosporium, the target timing will be at GS32 in the winter crop.

Powdery mildew

Growth stage 32 will also be the target timing for mildew in the winter crop but, with this disease, the fungicide timing may have to be adjusted, according to pathogen development. Disease in spring cereals tends to develop earlier and the most appropriate time for mildew may be GS30.

Brown rust & Net blotch

Brown rust and net blotch are diseases characterised by very rapid development during June and July, so the fungicide timing will be at GS37-39 rather than GS32.

Ramularia

The target timing will be boot stage GS45-49.

Leaf layer assessments

The fully emerged leaf at time of treatment will be tagged and assessments done on the tagged leaf and second leaf down (tag *minus* 1 leaf). This will provide information on eradicant activity. Assessments on the emerging leaf and subsequent leaf (tagged leaf *plus*1, tagged leaf *plus* 2) will demonstrate protectant activity.

On completion of leaf development, take a note of the position of the tagged leaves in relation to the flag leaf (e.g. flag leaf, F-1 f-2 etc.)

10.2 Treatments for Sites

10.3

Rhynchosporium	Powdery mildew	Net blotch	Brown rust	Ramularia
Site 1&3	*Site 2*	*Site4 & 5*	*Site 6*	*Site 7 & 8*
Opus	Opus	Opus	Opus	Opus
Kayak	Flexity	Kayak	HGCAB1	HGCAB2
HGCAB1	HGCAB1	Amistar	Amistar	Amistar
Comet 200	Torch extra	Comet 200	Torch extra	Proline
Proline	Cyflamid	Proline	Galileo	Fandango
Fandango	Proline	Fandango	Vivid	Bravo 500
Tracker	Flexity	HGCAB1	Proline	Tracker
Bravo	Talius	Tracker	Fandango	

Opus should remain as standard in all trials to provide common control standard throughout all trials over 6 years. Proline will be the future standard in all trials.

NOTE CHANGES in 2008

HGCA Codes	Product or company code
HGCA1	Acanto
HGCA2	Vivid
HGCA3	Bayer UK756 [Proline]
HGCA4	UK958 [Fandango]
HGCA5	2n BAS560 1.0 l/ha + Corbel 1.08 l/ha 1n BAS560 0.5 l/ha + Corbel 0.54 l/ha 0.5n BAS560 0.25 l/ha + Corbel 0.27 l/ha 0.25 n BAS560 0.125 l/ha + Corbel 0.135 l/ha.
HGCA6	BAS564 1.5 l/ha = full dose of co-formulation which contains 150 g ai 560 + 400 g ai fenpropimorph.
HGCA7	BAS507 (full dose 1.5 l/ha)
HGCA8	BAS549 (=Opus + BAS510) full dose 1.5 l/ha [BAS510 = boscalid][Tracker]
HGCA 9	Folpan
HGCA10	Talius (proquinazid) full dose 0.25 l/ha + fixed 0.25 l/ha corbel at all doses
HGCA11	Unix Chip 1.5 l/ha = 450gai / ha. The product contains 300g/l cyprodinil. Kayak
HGCAB1	Confidential
HGCAB2	Confiedential

Note HGCA 5 and HGCA 6 are same products but in different formulations. HGCA5 = Flexity + Corbel. HGCA6 has not been used in barley trials.

Site 1 and 3 (Rhynchosporium)

New code	Active ingredient	Product	Rate product/ha
1	Epoxiconazole	Opus	2.00 litre
2	Epoxiconazole	Opus	1.00 litre
3	Epoxiconazole	Opus	0.50 litre
4	Epoxiconazole	Opus	0.25 litre
21	Pyraclostrobin	Comet 200	2.50 litre
22	Pyraclostrobin	Comet 200	1.25 litre
23	Pyraclostrobin	Comet 200	0.625 litre
24	Pyraclostrobin	Comet 200	0.3125litre
25	Prothioconazole	Proline	1.60 litre
26	Prothioconazole	Proline	0.80 litre
27	Prothioconazole	Proline	0.40 litre
28	Prothioconazole	Proline	0.20 litre
29	Prothioconazole + Fluoxastrobin	Fandango	2.50 litres
30	Prothioconazole + Fluoxastrobin	Fandango	1.25 litres
31	Prothioconazole + Fluoxastrobin	Fandango	0.625 litre
32	Prothioconazole + Fluoxastrobin	Fandango	0.3125 litres
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	
36	Untreated	----	
57	Chlorothalonil	Bravo 500	4.0 l/ha
58	Chlorothalonil	Bravo 500	2.0 l/ha
59	Chlorothalonil	Bravo 500	1.0 l/ha
60	Chlorothalonil	Bravo 500	0.5 l/ha
65	Epoxiconazole+boscalid	Tracker	3.0
66	Epoxiconazole+boscalid	Tracker	1.5
67	Epoxiconazole+boscalid	Tracker	0.75
68	Epoxiconazole+boscalid	Tracker	0.375
85	Cyprodinil	Kayak	3.0 litre
86	Cyprodinil	Kayak	1.5 litre
87	Cyprodinil	Kayak	0.75 litre
88	Cyprodinil	Kayak	0.375 litre
93	HGCAB1	HGCAB1	2n
94	HGCAB1	HGCAB1	n
95	HGCAB1	HGCAB1	0.5n
96	HGCAB1	HGCAB1	0.25n

Site 2 (Powdery mildew)

New code	Active ingredient	Product	Rate product/ha
1	Epoxiconazole	Opus	2.00 litre
2	Epoxiconazole	Opus	1.00 litre
3	Epoxiconazole	Opus	0.50 litre
4	Epoxiconazole	Opus	0.25 litre
25	Prothioconazole	Proline	1.60 litre
26	Prothioconazole	Proline	0.80 litre
27	Prothioconazole	Proline	0.40 litre
28	Prothioconazole	Proline	0.20 litre
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	
36	Untreated	----	
37	Quinoxyfen	Fortress	0.60 litre
38	Quinoxyfen	Fortress	0.30 litre
39	Quinoxyfen	Fortress	0.15 litre
40	Quinoxyfen	Fortress	0.075 litre
73	Flexity	Metrafenone	1.0
74	Flexity	Metrafenone	0.5
75	Flexity	Metrafenone	0.25
76	Flexity	Metrafenone	0.125
77	Cyflufenamid	Cyflamid	1.00 litre
78	Cyflufenamid	Cyflamid	0.50 litre
79	Cyflufenamid	Cyflamid	0.25 litre
80	Cyflufenamid	Cyflamid	0.125 litre
81	Spiroxamine	Torch extra	1.8 l/ha
82	Spiroxamine	Torch extra	0.9 l/ha
83	Spiroxamine	Torch extra	0.45 l/ha
84	Spiroxamine	Torch extra	0.225 l/ha
89	Proquinazid	Talius	0.5
90	Proquinazid	Talius	0.25
91	Proquinazid	Talius	0.125
92	Proquinazid	Talius	0.0625
93	HGCAB1	HGCAB1	2n
94	HGCAB1	HGCAB1	n
95	HGCAB1	HGCAB1	0.5n
96	HGCAB1	HGCAB1	0.25n

Site 4 and 5 (Net blotch)

New code	Active ingredient	Product	Rate product/ha
1	Epoxiconazole	Opus	2.00 litre
2	Epoxiconazole	Opus	1.00 litre
3	Epoxiconazole	Opus	0.50 litre
4	Epoxiconazole	Opus	0.25 litre
21	Pyraclostrobin	Comet 200	2.50 litre
22	Pyraclostrobin	Comet 200	1.25 litre
23	Pyraclostrobin	Comet 200	0.625 litre
24	Pyraclostrobin	Comet 200	0.313 litre
25	Prothioconazole	Proline	1.60 litre
26	Prothioconazole	Proline	0.80 litre
27	Prothioconazole	Proline	0.40 litre
28	Prothioconazole	Proline	0.20 litre
29	Prothioconazole+ fluoxastrobin	Fandango	2.50 litres
30	Prothioconazole+ fluoxastrobin	Fandango	1.25 litres
31	Prothioconazole+ fluoxastrobin	Fandango	0.625 litre
32	Prothioconazole+ fluoxastrobin	Fandango	0.3125 litres
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	---
36	Untreated	----	---
45	Azoxystrobin	Amistar	2.00 litre
46	Azoxystrobin	Amistar	1.00 litre
47	Azoxystrobin	Amistar	0.50 litre
48	Azoxystrobin	Amistar	0.25 litre
65	Epoxiconazole+bo scalid	Tracker	3.0
66	Epoxiconazole+bo scalid	Tracker	1.5
67	Epoxiconazole+bo scalid	Tracker	0.75
68	Epoxiconazole+bo scalid	Tracker	0.375
85	Cyprodinil	Kayak	3.0 litre
86	Cyprodinil	Kayak	1.5 litre
87	Cyprodinil	Kayak	0.75 litre
88	Cyprodinil	Kayak	0.375 litre
93	HGCAB1	HGCAB1	2n
94	HGCAB1	HGCAB1	n
95	HGCAB1	HGCAB1	0.5n
96	HGCAB1	HGCAB1	0.25n

Site 6 (brown rust)

New code	Active ingredient	Product	Rate product/ha
1	Epoxiconazole	Opus	2.00 litre
2	Epoxiconazole	Opus	1.00 litre
3	Epoxiconazole	Opus	0.50 litre
4	Epoxiconazole	Opus	0.25 litre
17	Picoxystrobin	Acanto	2.00 litre
18	Picoxystrobin	Acanto	1.00 litre
19	Picoxystrobin	Acanto	0.50 litre
20	Picoxystrobin	Acanto	0.25 litre
21	Pyraclostrobin	Comet 200	2.50 litre
22	Pyraclostrobin	Comet 200	1.25 litre
23	Pyraclostrobin	Comet 200	0.625 litre
24	Pyraclostrobin	Comet 200	0.313 litre
25	Prothioconazole	Proline	1.60 litre
26	Prothioconazole	Proline	0.80 litre
27	Prothioconazole	Proline	0.40 litre
28	Prothioconazole	Proline	0.20 litre
29	Prothioconazole+ fluoxastrobin	Fandango	2.50 litres
30	Prothioconazole+ fluoxastrobin	Fandango	1.25 litres
31	Prothioconazole+ fluoxastrobin	Fandango	0.625 litre
32	Prothioconazole+ fluoxastrobin	Fandango	0.3125 litres
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	
36	Untreated	----	
45	Azoxystrobin	Amistar	2.00 litre
46	Azoxystrobin	Amistar	1.00 litre
47	Azoxystrobin	Amistar	0.50 litre
48	Azoxystrobin	Amistar	0.25 litre
81	Spiroxamine	Torch extra	1.8 litre
82	Spiroxamine	Torch extra	0.9 litre
83	Spiroxamine	Torch extra	0.45 litre
84	Spiroxamine	Torch extra	0.225 litre
93	HGCAB1	HGCAB1	2n
94	HGCAB1	HGCAB1	n
95	HGCAB1	HGCAB1	0.5n
96	HGCAB1	HGCAB1	0.25n

Site 7 and 8 (Ramularia)

New code	Active ingredient	Product	Rate product/ha
1	Epoxiconazole	Opus	2.00 litre
2	Epoxiconazole	Opus	1.00 litre
3	Epoxiconazole	Opus	0.50 litre
4	Epoxiconazole	Opus	0.25 litre
21	Pyraclostrobin	Comet 200	2.50 litre
22	Pyraclostrobin	Comet 200	1.25 litre
23	Pyraclostrobin	Comet 200	0.625 litre
24	Pyraclostrobin	Comet 200	0.313 litre
25	Prothioconazole	Proline	1.60 litre
26	Prothioconazole	Proline	0.80 litre
27	Prothioconazole	Proline	0.40 litre
28	Prothioconazole	Proline	0.20 litre
29	Prothioconazole+ Fluoxastrobin	Fandango	2.50 litres
30	Prothioconazole+ Fluoxastrobin	Fandango	1.25 litres
31	Prothioconazole+ Fluoxastrobin	Fandango	0.625 litre
32	Prothioconazole+ Fluoxastrobin	Fandango	0.3125 litres
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	
36	Untreated	----	
45	Azoxystrobin	Amistar	2.00 litre
46	Azoxystrobin	Amistar	1.00 litre
47	Azoxystrobin	Amistar	0.50 litre
48	Azoxystrobin	Amistar	0.25 litre
57	Chlorothalonil	Bravo 500	4.0 litre
58	Chlorothalonil	Bravo 500	2.0 litre
59	Chlorothalonil	Bravo 500	1.0 litre
60	Chlorothalonil	Bravo 500	0.5 litre
65	Epoxiconazole+boscalid	Tracker	3.0 litre
66	Epoxiconazole+boscalid	Tracker	1.5 litre
67	Epoxiconazole+boscalid	Tracker	0.75 litre
68	Epoxiconazole+boscalid	Tracker	0.375 litre
97	HGCAB2	HGCAB2	2n
98	HGCAB2	HGCAB2	N
99	HGCAB2	HGCAB2	0.5n
100	HGCAB2	HGCAB2	0.25n

HGCAB2 to be confirmed. If use refused, use HGCAB1 instead

EXPERIMENT DESIGN AND STATISTICAL ANALYSIS

The layout for each field experiment will be a randomised complete block with three replicates of each treatment including the untreated control plots.

MATERIALS

Materials required are detailed in the appropriate SOPs.

METHODS

Field operations

Plot size to be in the range 24-60 m^2.

Fungicide to be applied as a medium spray quality (as defined by BCPC) in 200-300 litres water/ha at 200-300 kPa pressure)

Other treatments (fertiliser, micronutrients, herbicides, molluscicides, insecticides, growth regulators) should follow good farm practice, but should be risk-averse to ensure, so far as is possible, that the trial is not affected by other factors such as BYDV, lodging or serious weed or pest infestation.

The whole plot or, for larger plots, a central area of at least 20 m^2, should be harvested

ASSESSMENTS AND RECORDS

Where an SOP or an option within an SOP is mentioned, the instruction contained therein must be followed precisely unless stated otherwise in the text.

Disease Assessments

It is essential that one person carries out all the disease assessments on each assessment date, but assistance will be required in sampling and recording. In addition, careful observations and quantitative records should be made when non-target diseases, disorders, pests or other treatment effects are detected in the experiment.

Foliar diseases and green leaf area

All plots should be assessed for foliar diseases on two occasions, approximately 3 and 6 weeks after the treatments are applied. The precise timings are at the discretion of the Site Manager.

For each plot to be assessed, 10 stems should be taken, at 10 points distributed approximately equally along the length of the plot and taken a minimum of 30 cm into the crop from the pathways. **An alternative method is to assess leaves in situ.** If two people are sampling each should collect 5 stems from opposite sides of the plot approximately equally spaced along the length of the plot. Where possible, assessments should be carried out at the end of each plot by one assessor, which

would obviate the need for polythene bags for samples. Record percentage area affected by each disease, and percentage green leaf area.

Mean disease and green leaf area scores should be recorded for each individual layer based on a 10 stem sample. These may be produced by:

Recording disease and green leaf area affected on each leaf individually and computing a mean subsequently.

Summing disease and green leaf area assessments for each of the 10 leaves in each leaf layer in the field and recording a mean value per plot in the field.

Recording a single figure for each disease/green leaf score for each leaf layer. This can be done by arranging stems in the hand for assessment with individual leaf layers aligned (i.e. all flag leaves held together and fanned out for assessment, then this process is repeated for leaf two and leaf three etc.). Where this method is employed, all 10 stems in a sample can be assessed in a single group or, alternatively, each 10 stem sample can be subdivided into 2 groups of 5 stems and a single figure recorded for each leaf layer for each group of 5 stems. A mean from the 2 scores from each set 5 stems should then be calculated for each plot.

Continue to record %GLA and disease for each leaf layer until all leaves are completely senescent.

Ear diseases

If ear assessments are required, Initially assess diseases on 10 ears per plot (use the plant samples collected for foliar disease assessment) at GS 85 in each untreated plot. Assess all plots only is more than 10% ear area is affected in untreated plots.

Stem base diseases

Eyespot assessments are not required unless treatment specific lodging is present in the trial

If eyespot assessment is required, record stem base diseases on 25 stems from untreated plots at GS 31-32. Record on a stem by stem basis the presence or absence of individual diseases and, for eyespot, the severity expressed as the number of leaf sheaths penetrated (i.e. showing brown staining).

On winter sown crops at GS 75, assess stem base diseases on 25 stems per plot in each untreated plot. If >25% stems are affected by moderate or severe lesions of any disease or if >10% stems with severe lesions of any disease, assess all plots.

Growth Stage

Record growth stage on each assessment date.

Lodging

Record the % plot area lodged just prior to harvest if plots are affected by lodging.

Grain Yield

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

Grain Quality

Specific weight to be recorded, expressed at 85% dry matter.
Screenings (2.5 mm sieve) to be recorded on spring barley trials.

Crop Records

The following site details will be recorded:

Location and grid reference
Soil type and soil series
Soil texture
Drainage
Previous cropping (4 years; refer to the year of harvest)
Straw disposal method
Previous cultivations
Sowing date
Seed rate
Seed treatment
Spray equipment used including nozzle specification
Herbicides)
Insecticides)
Growth regulators) Give products, active ingredients,
Fertilisers) application rates and dates
Molluscicides)
Trace elements)
Harvest date

Procedures in the event of delays

If a fungicide application is delayed, it should be applied on the next possible opportunity. If prolonged adverse conditions result in delays of over 7 days, notify the Study Director promptly.

Whenever possible, samples should be assessed on the date of collection. Where this is not possible, samples may be kept in a refrigerator prior to assessment for up to 3 days in the case of foliar and ear disease assessments, up to 6 days for growth analysis and up to 10 days for stem-base disease assessments.

DATA HANDLING

Data collation

Data should be transferred to Excel spreadsheets as soon as possible after collection. Send disease data when complete to simon.oxley@sac.ac.uk.

Standard spreadsheets for data collation will be provided for each site by BioSS
Disease data should be entered by 31 August in the year of collection, and harvest data by 30 September in the year of collection.
YOU MUST USE THE SPREADSHEET PROVIDED FOR 2008 TRIALS.

REPORTS

Site reports to be produced be each Site Manager by 30 September each year, to a format to be supplied by the Reports Co-ordinator.

Annual Interim Reports to be submitted to the HGCA by 31 December each year, or such other date as specified by the HGCA.

Final Report to be submitted to the HGCA by 31 March 2009.

RETENTION OF RECORDS, SPECIMENS AND SAMPLES

All records should be retained by Site Managers for a minimum of 10 years. Thereafter, they may not be discarded without permission from the Study Director.

SOP LIST (SAC)

The SOPs refer to SAC quality control system. ADAS, TEAGASC and Morley (TAG) can refer to their own as appropriate.

Equipment

EQU 001 Fertiliser applicator calibration
EQU 002 Fertiliser applicator cleaning
EQU 003 Fertiliser application
EQU 006 The calibration, operation and cleaning of commercial seed drill
EQU 012 Sprayer calibration and operation- knapsack
EQU 014 Pedestrian operated sprayer cleaning
EQU 016 The use and calibration of weigh balances
EQU 019 Combine harvester setting and operation
EQU 028 Use of drying ovens
EQU 020 Plot yield balance calibration and operation

TRIAL

TRL 001 Trial design
TRL 002 Site identification and selection
TRL 003 Soil analysis
TRL 004 fertiliser requirements for sites
TRL 005 calculation of fertiliser rates
TRL 006 Seed bed preparation
TRL 007 Marking out trials (combinable crops)
TRL 010 Burning out plots to length
TRL 011 Plot labelling
TRL 012 Grain /seed sampling
TRL 013 Grain/seed storage
TRL 014 Grain/seed cleaning
TRL 020 Crops sampling, labelling, transport, storage and disposal policy
TRL 021 Crop destruction and disposal policy
TRL 022 % Dry matter determination

TRL 023 Calculation of corrected yield

CEREALS
CER 002 Cereal crop maintenance
CER 003 Cereal growth stage assessment
CER 004 Procedure for detailed disease and green leaf assessments in cereals
CER 006 Procedure for detailed cereal ear assessments
CER 008 Ripening / harvest date determination in cereals
CER 009 Lodging / brackling / necking and leaning assessments in cereals
CER 017 Specific weight determination in cereals
CER 018 Cereals emergence, vigour and establishment assessments in the field
CER 019 Tiller counts in cereals

DISTRIBUTION

Study Director:	Simon Oxley
Reports Co-ordinator:	Simon Oxley
Site Manager, Site 1,2 & 7	Simon Oxley
Site Manager Site 3	David Lockley
Site Manager, Sites 4	Peter Gladders
Site Manager, Sites 5 & 6	Marion Self
Site manager site 8	Richard Hackett
For information	Tony Hunter

Disposal of test system: crop destruction for double dose and coded materials.

Location of raw data at individual organisation, but full data set will be archived at http://www.bioss.sari.ac.uk/afdbarley/ at end of season
User name and password protected. If forgotten, contact Simon by email

Reporting date Final report March 2009

Archiving of documentation and samples. SAC

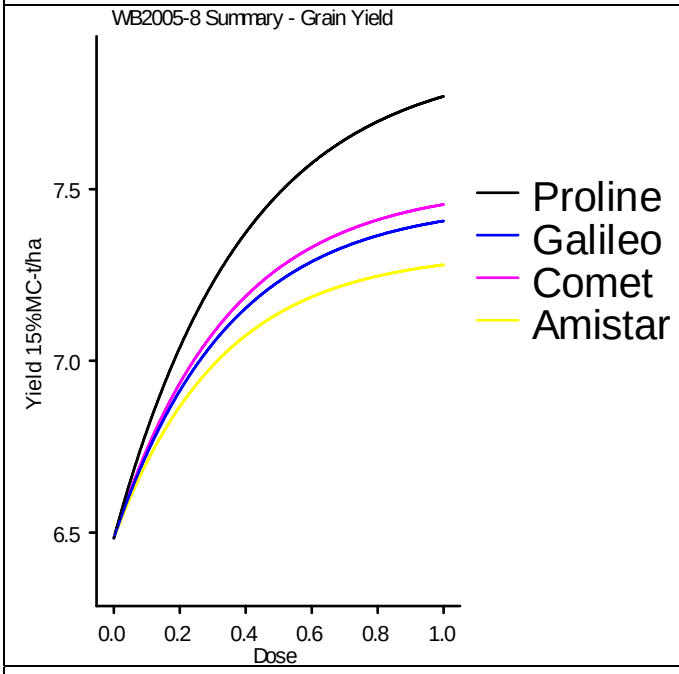
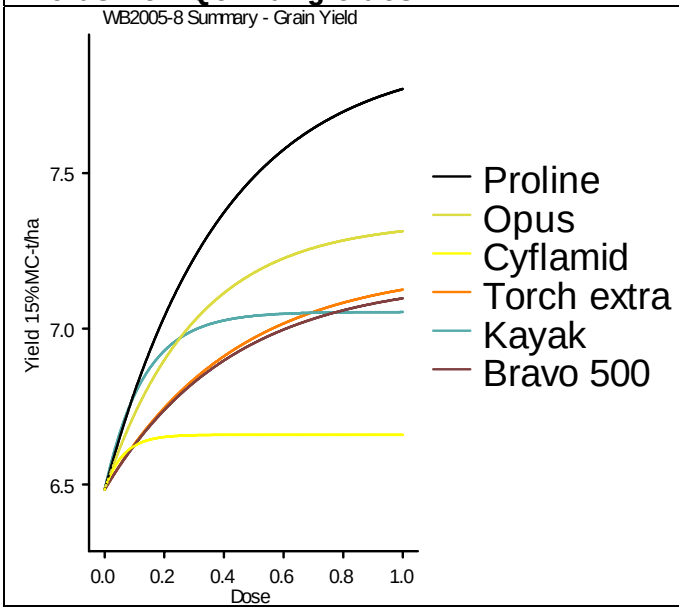
Study personnel: Study Director(s), Simon Oxley SAC

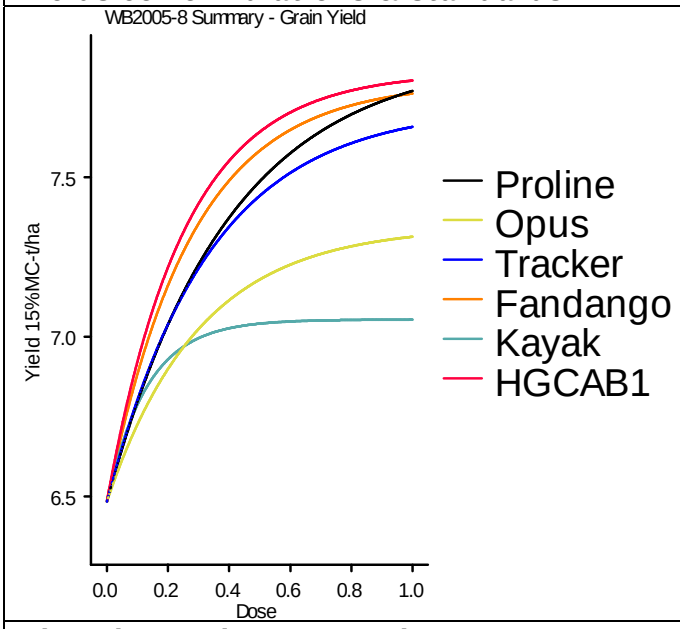
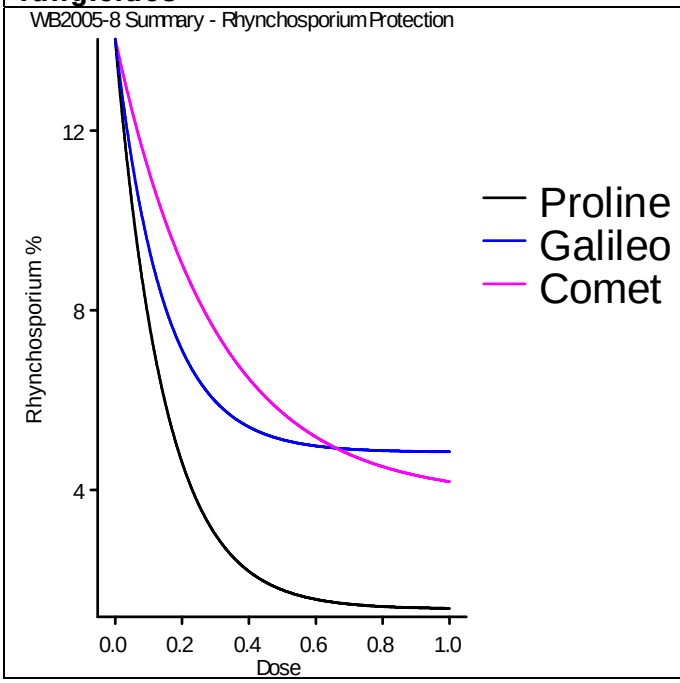
END of PROTOCOL

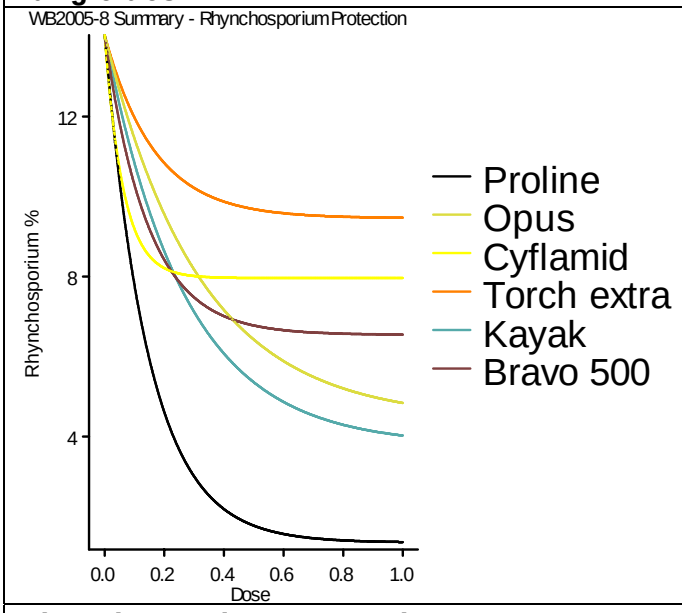
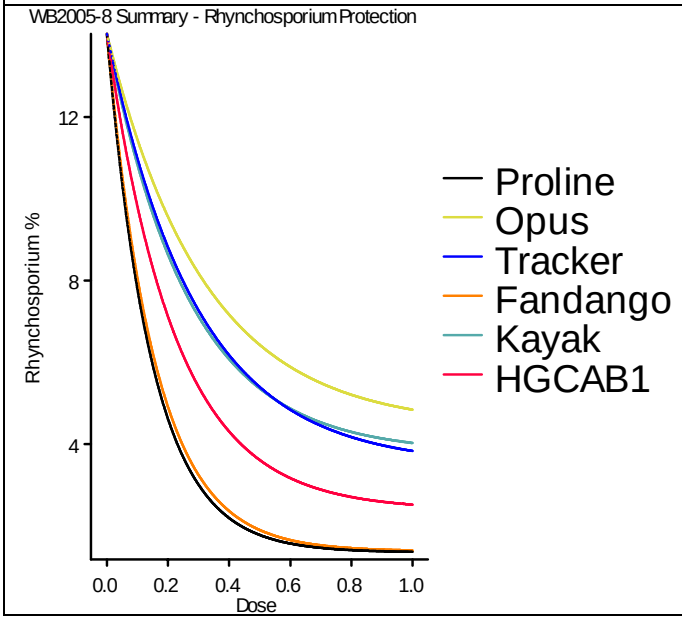
QA Signature	Date

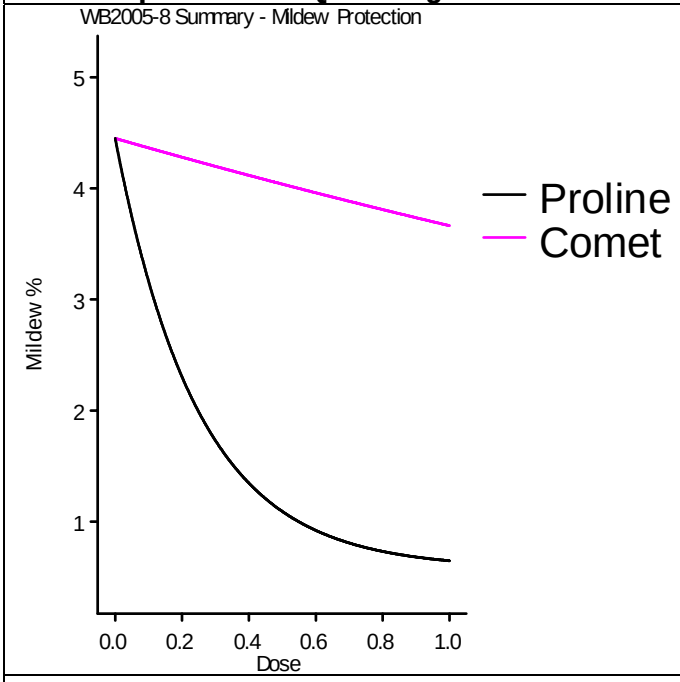
Appendix 2 Winter barley curve summaries for yield and disease protection 2005-2008

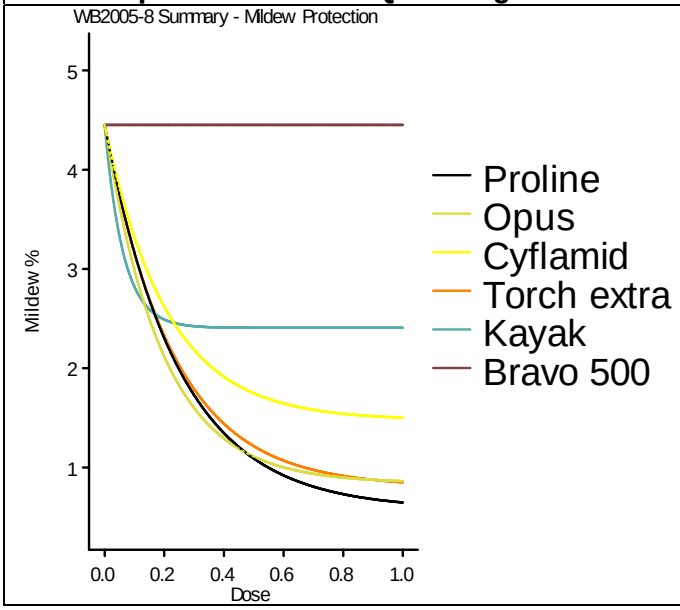
Graph lines are in colour. To assist interpretation for black and white copies of this report, the order of the lines at full dose are given on the right hand side

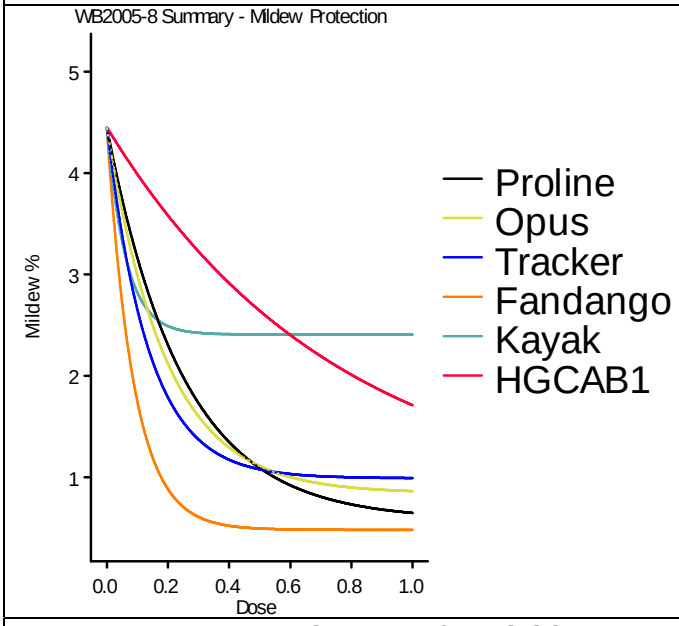
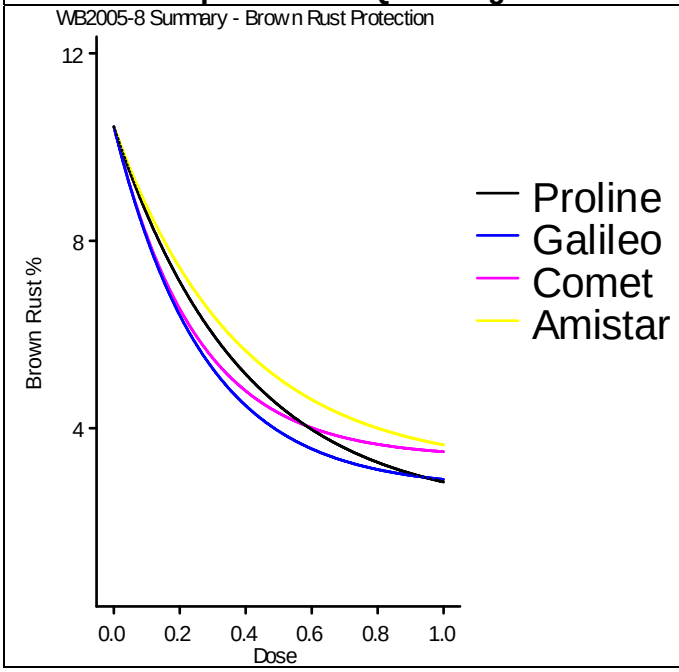
Yields QoI fungicides	**Order of fungicides at full dose (Proline standard used throughout)**
	Proline Comet Galileo Amistar
Yields non QoI fungicides	**Order of fungicides at full dose**
	Proline Opus Torch extra Bravo Kayak Cyflamid

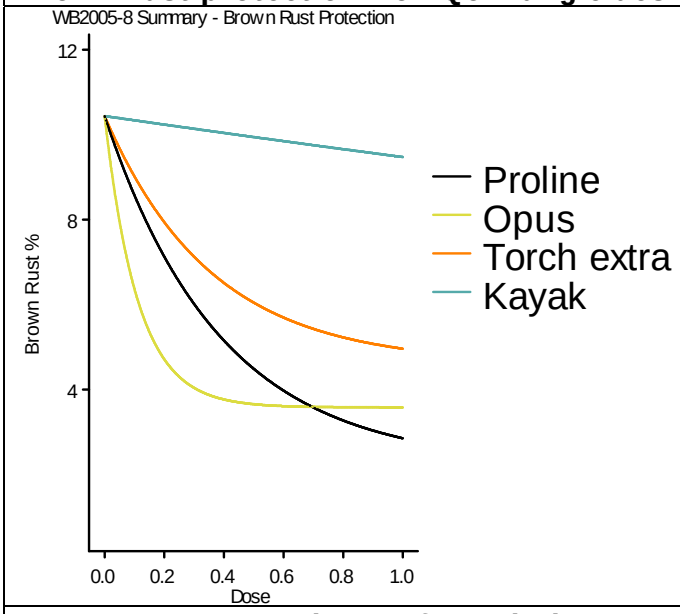
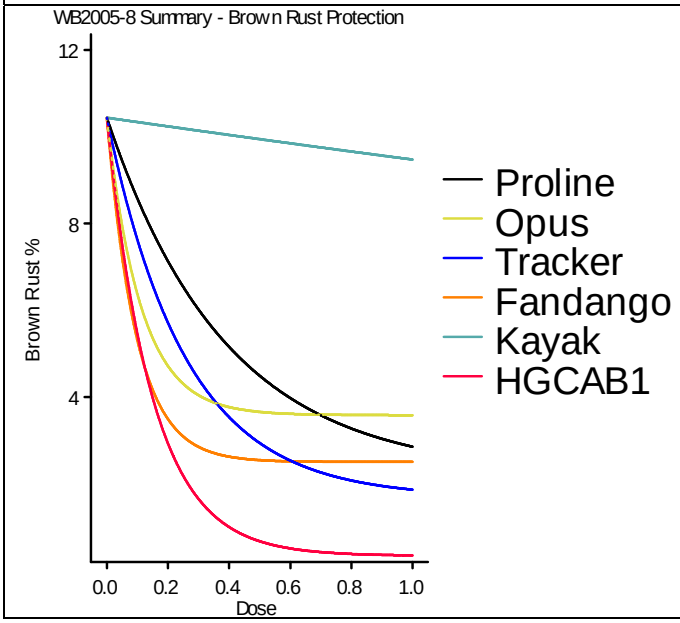
Yields co-formulations & standards	Order of fungicides at full dose
	HGCAB1 Fandango Proline Tracker Opus Kayak
Rhynchosporium protection QoI fungicides	**Order of fungicides at full dose**
	Galileo Comet Proline

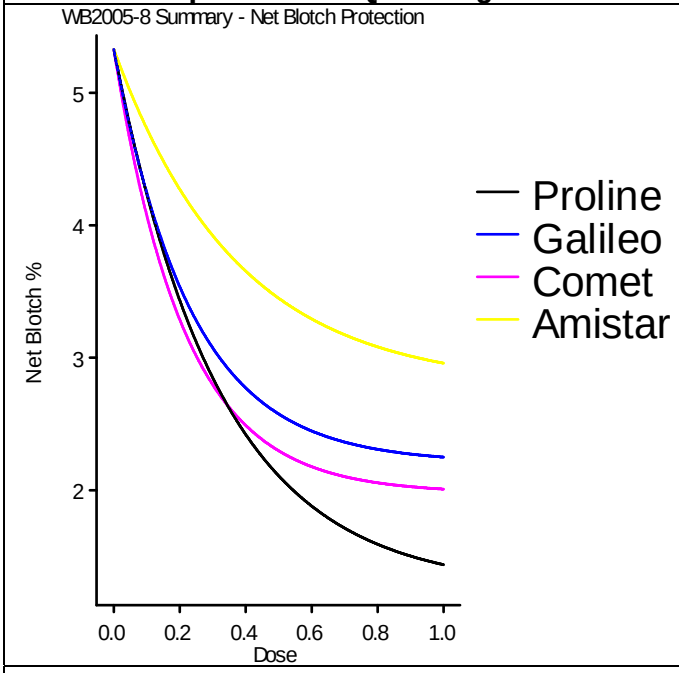
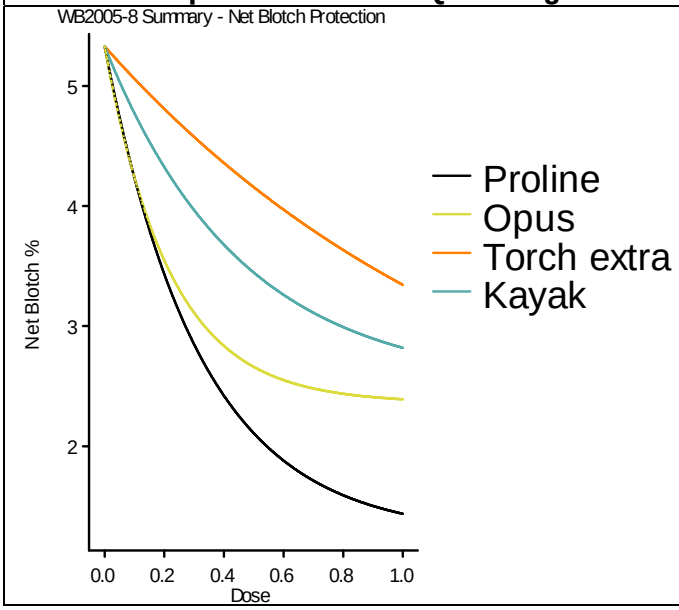
Rhynchosporium protection non QoI fungicides	Order of fungicides at full dose
	Torch extra Cyflamid Bravo Opus Kayak Proline
Rhynchosporium protection co-formulations & standards	**Order of fungicides at full dose**
	Opus Kayak Tracker HGCAB1 Fandango Proline

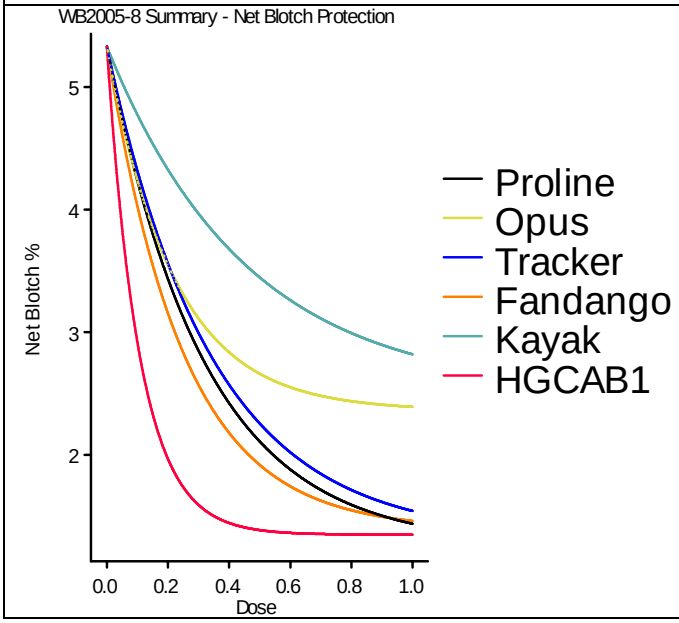
Mildew protection QoI fungicides	Order of fungicides at full dose
	Comet Proline

Mildew protection non QoI fungicides	Order of fungicides at full dose
	Bravo Kayak Cyflamid Torch extra Opus Proline

Mildew protection co-formulations & standards	Order of fungicides at full dose
	Kayak HGCAB1 Tracker Opus Proline Fandango
Brown rust protection QoI fungicides	**Order of fungicides at full dose**
	Amistar Comet Proline Galileo

Brown rust protection Non QoI fungicides	Order of fungicides at full dose
	Kayak Torch extra Opus Proline
Brown rust protection co-formulations & standards	**Order of fungicides at full dose**
	Kayak Opus Proline Fandango Tracker HGCAB1

Net blotch protection QoI fungicides	Order of fungicides at full dose
	Amistar Galileo Comet Proline
Net blotch protection non QoI fungicides	**Order of fungicides at full dose**
	Torch extra Kayak Opus Proline

Net blotch protection co-formulations & standards	Order of fungicides at full dose
	Kayak Opus Tracker Proline Fandango HGCAB1