Project Report No. 366

May 2005

Price: £9.00

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

by

S J P Oxley[1] and E A 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 is the final report of a forty-four month project that commenced in August 2001. The work was funded by a contract for £210,667 from the Home-Grown Cereals Authority (Project 2496).

Abstract

The aim of the research was to provide an independent source of information about the activity of current and newly introduced fungicides against the major barley diseases. 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 is important to ensure growers receive 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 recent introduction of the fungicides Proline and Fandango provide a major step forward in the control of rhynchosporium whilst also delivering good control of powdery mildew, net blotch, brown rust and ramularia. Effective disease control was achieved with these fungicides alongside a yield benefit, which makes these new fungicides cost-effective to use. The research also highlighted fungicides, which either show disease activity limited to one disease, or which are primarily eradicative or protective in activity. These specific fungicides are an essential component of the spectrum of fungicides available to a grower, since they have different modes of action to the main broad-spectrum strobilurin and triazole fungicides. More specific fungicides can however be more difficult to use, which is why the tables developed through this research on disease eradicant and protectant activity, yield and green leaf area retention, can assist growers to use them in combination with the more broad-spectrum fungicides.

Getting the results out to the HGCA levy-payers quickly meant the procedures in assessing trials, collecting data, analysis and dissemination were all focussed on this aim. The data collected over three years will be a useful foundation for future research. It will provide a reliable platform to determine how new fungicides approved for use in 2005, change in their activity when used more widely as opposed to their limited use in field trials up to now.

Results were reported in a SEERAD 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 are being developed as part of an Appropriate Dose Curve Generator. This web-based tool will allow growers to compare dose curves generated from this three year 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 varieties is covered by the Home-Grown Cereals Authority through Cereal Evaluation Ltd (CEL) and the production of the HGCA Recommended List (RL). This research project focuses on the activity of 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 the three year project, a total of sixteen winter barley field trials were carried out in the UK. Just as the RL uses robust fungicide programmes to achieve the genetic potential of varieties, this research used the most susceptible varieties in high risk disease situations to assess the potential of the fungicides. In all cases the trials relied on natural infection for testing.

The diseases targeted were rhynchosporium, brown rust, powdery mildew and net blotch. In a separate series of trials funded outwith this project, three spring barley trials in Scotland and Eire targeted the leaf spotting complex caused by ramularia and also by physiological stress.

The field trials were managed using typical local inputs of herbicides, fertilisers 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 plot yields were weighed and specific weights recorded.

This experimental approach is a severe test for fungicides and is possibly "unfair" for fungicides which may have a narrow disease spectrum, or narrow protectant or eradicant activities. Such issues have been addressed in a previous HGCA research project (HGCA Project Report 315) which looked at the

contribution specific fungicides have in mixtures. This is also being addressed further in a current barley research project focussing on fungicide mixtures.

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 first two years then all three years was analysed. The three 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 trends can vary and poor control should not automatically lead to a conclusion of a decline in efficacy. One reason for this is down to the different levels of disease pressure in each season. Getting 100% control in a year when 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 period of this research, strobilurin (QoI) resistance to powdery mildew developed from a low level to a high level. In 2004, there was evidence that resistance had occurred to net blotch, but it is unlikely this influenced the field trials in this study. Rhynchosporium resistance to the triazole fungicide epoxiconazole (Opus) has been reported (HGCA Project Report 315), but in the rhynchosporium field trials in this study, this fungicide gave good control.

Curves were fitted to the results and an appropriate fungicide dose curve generator is being 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. It is expected to be available in May 2005 and will be available at www.sac.ac.uk/crops. This approach will allow levy payers faster access to new data on an annual basis.

Key results

Fungicide activity data for disease protection and eradication are given in Table 1 on the basis of plusses, with four plusses giving best control. The plusses were derived from the level of disease control achieved from a half dose. This dose was chosen, since it is one which is easier for growers to identify as a dose they are likely to use on a crop. It is also a dose for which actual data exist, making the data more precise than using a dose extrapolated from the generated curves.

Rhynchosporium

The fungicides Fandango (prothioconazole + fluoxastrobin) and Proline (prothioconazole) achieved the best protection and eradication of rhynchosporium. This was consistent over three years. These new fungicides have only recently become commercially available, so any slippage in control following their widespread use will be monitored in the following project. Opus (epoxiconazole), Acanto (picoxystrobin) and Vivid (pyraclostrobin) achieved the next best control. Where more insensitive strains of the fungus exist to Opus, control will be diminished. Twist (trifloxystrobin) gave good protectant activity against rhynchosporium, but was weaker on eradication than Acanto and Vivid.

Table 1 Fungicide activity against the major winter barley diseases

Fungicide	Rhynchosporium		Powdery mildew		Brown rust		Net blotch	
	Protection	Eradication	Protection	Eradication	Protection	Eradication	Protection	Eradication
Unix	++	+	++	+	+	+	+++	++
Corbel	++	++	++	+++	++	++++	+	-
Neon	++	++	++	++	+++	++++	++	-
Flexity + Corbel	-	-	++++	++	-	-	-	-
Acanto	+++	+++	-	-	++++	++++	+++	+++
Vivid	+++	+++	-	-	++++	++++	+++	+++
Amistar	++	+	-	-	++++	++++	+++	++
Twist	+++	+	-	-	++	++	++	++
Fortress	-	-	+++	+	-	-	-	-
Opus	+++	+++	++	+	+++	++++	+	++
Proline	++++	++++	+++	++	+++	++++	++	+++
Tracker	+++	++	++	+	+++	++++	+	++
Fandango	++++	++++	+++	++	++++	++++	+++	+++

Disease control	Comment	% control at half dose
-	No data or not recommended	-
+	Poor control	0-25%
++	Moderate control	26-50%
+++	Good control	51-75%
++++	Very good control	76-100%

Neon (spiroxamine), Corbel (fenpropimorph) and Unix (cyprodinil) gave moderate levels of protection. Corbel and Neon also gave moderate eradication, whilst Unix was poor. The morpholines are known to contribute to rhynchosporium control through a short-lived knock-down effect. This is only likely to be seen where they are used in mixtures and are less obvious under this experimental design.

The data show the strobilurin (or Quinoline outside Inhibitors-QoI) fungicides remain effective against rhynchosporium and a key fungicide group to control the disease. The introduction of Proline provides a new effective fungicide to control rhynchosporium. Further work will look at effective mixing partners to help this fungicide remain active in the next few years.

Powdery mildew

Powdery mildew eradication was best with Corbel. Flexity (metrafenone) + Corbel also achieved good eradication along with Neon, Proline and Fandango. Proline and Fandango rely on a triazole component to control mildew, and it is likely this control may diminish following widespread usage. Mildew protection was best with Flexity + Corbel, Fortress (quinoxyfen), Proline and Fandango.

Brown rust

Brown rust was generally more straightforward to control with fungicides than other diseases. Many fungicides achieved very good eradication, with the exception of Unix and Twist. Both of these fungicides are recognised to be weak against this disease. For brown rust protection many of the QoI fungicides (Acanto, Vivid, and Amistar) had the edge, followed by the triazole fungicides (Opus and Proline). The morpholines (Corbel and Neon), Twist and Unix were the least effective. Good eradication but poor protection from the morpholines suggests these types of fungicides lack long term persistence. The good control achieved with Proline is in contrast to the control achieved for wheat brown rust.

Net blotch

Net blotch results are limited to 2004 since disease levels were very low in 2002 and 2003. QoI resistance has started to be found in the UK, but it is unlikely to have been an issue at the field sites. Best protection was achieved with the QoI fungicides (Acanto, Vivid, Amistar), Unix and Fandango. The triazole fungicides were less effective, but Proline gave better protection than Opus. For eradication, Acanto, Vivid, Proline and Fandango achieved the best control.

Yields

As would be expected, 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) were achieved in varieties where the dominant disease was rhynchosporium (1.09 t/ha), and brown rust (1.03 t/ha). Controlling powdery mildew achieved a lower disease benefit (0.85 t/ha).

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

Mildew yields at half dose		Rhynchosporium yields at half dose		Brown rust yields at half dose		
Fungicide	**t/ha**	**Fungicide**	**t/ha**	**Fungicide**	**t/ha**	**Best yield**
Proline	7.25	Fandango	6.48	Fandango	7.99	
Flexity+Corbel	6.98	Proline	6.33	Acanto	7.85	
Opus	6.95	Tracker	6.23	Vivid	7.81	
Acanto	6.86	Twist	5.99	Proline	7.72	
Unix	6.82	Vivid	5.90	Twist	7.71	
Neon	6.79	Acanto	5.84	Amistar	7.56	
Corbel	6.67	Opus	5.83	Opus	7.52	
Fortress	6.56	Unix	5.80	Neon	7.36	
-	-	Corbel	5.65	Unix	7.08	
Untreated	6.40	Untreated	5.39	Untreated	6.96	**Lowest yield**

The best yield performers in rhynchosporium trials were Proline and Fandango and Tracker (limited data). Where brown rust was targeted, Fandango and many of the QoI fungicides achieved the best results. For powdery mildew, Proline and Flexity + Corbel achieved the best results.

At the bottom end of the table, Fortress and the morpholines 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 larger green leaf area, it can be expected that there is a better opportunity to get a higher 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 £70/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 at fungicides used at half dose. The new fungicides Proline, Fandango and Tracker all achieved high scores alongside Flexity + Corbel and Vivid. No fungicide scored a one plus rating, even though some of the specific fungicides would have been under a severe test.

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

Fungicide	**Yield response**	**Green leaf area retention**	**Value for money**
Unix	++	++	+++
Corbel	+	++	++
Neon	++	++	+++
Flexity + Corbel	+++	+++	++++
Acanto	+++	++	+++
Vivid	+++	++	++++
Amistar	+++	+++	+++
Twist	+++	++	+++
Fortress	+	++	++
Opus	++	++	+++
Proline	+++	+++	++++
Tracker	+++	++	++++
Fandango	++++	+++	++++

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 £70/t**
Untreated	-	£400
+	Poor	£401-425
++	Moderate	£426-450
+++	Good	£451-£475
++++	Very good	>£476

Spring barley

Ramularia and abiotic leaf spots

The best control of ramularia was achieved with Bravo and Proline. Opus also achieved good control. The QoI fungicides were less effective. Whether there has been a shift in the sensitivity of ramularia or whether the QoI fungicides were never very effective against the disease is currently being investigated in an ongoing joint SEERAD and HGCA project (RD-2004-3024). Abiotic leaf spots were reduced with Bravo, Proline, Opus and Vivid. It is not unusual for fungicides to influence a non-fungal effect. It is possible that the active ingredients or the formulations have antioxidant properties which reduce the level of leaf spotting caused by oxidative stress.

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

Fungicide	Ramularia protection	Abiotic leaf spot protection	Yield response	Green leaf retention
Bravo	+++	+++	++	+++
Acanto	+	-	-	-
Vivid	++	++	++	++
Opus	+++	+++	++	+++
Proline	+++	+++	++	+++
Fandango	+++	+++	++	+++

See categories used in winter barley tables above for definition of plusses (Table 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 SEERAD (in Scotland) and Defra (in England). The severity of rhynchosporium is greatest in Scotland and the south and west of England. Net blotch is currently rare, but this situation may change with the recent discovery of resistance to strobilurin (QoI) fungicide. Powdery mildew is found in all areas, but in 2003, levels were higher in the north of England. Brown rust is more common in the west and north of England, but less of an issue in Scotland. Ramularia is now a major problem in Scotland, particularly in spring barley, but is currently rare in England. Yellow rust is currently very rare, but outbreaks do occur in untreated variety trials.

Table 5 Average disease levels (%) in commercially treated crops in July 2003 [Defra & SEERAD data]

Region	West England	North England	South England	East England	Scotland
rhynchosporium	3.6	2.7	4.2	1.5	5.0
net blotch	0.2	0.2	0.8	0.1	0.1
mildew	0.3	0.8	0	0.2	0.3
yellow rust	0	trace	0	0	0
brown rust	0.7	0.1	0.5	trace	0
ramularia	-	-	-	-	6.3

trace = < 0.05
Numbers of crops assessed: England (West - 51 crops, North - 87 crops, South - 9 crops, East - 49 crops), Scotland 50.
-No data

Fungicide use and resistance can also influence disease, and the introduction of a new fungicide showing specific activity can transform the spectrum and severity of disease. One example was the introduction of Quinone outside Inhibitor (QoI) fungicides, which are commonly known as strobilurins. Before their introduction, net blotch was a difficult disease to control when the key fungicide used was epoxiconazole

(Opus). Disease levels decreased following the introduction of QoI fungicides, but the detection of QoI resistance to *Pyrenophora teres* may change the importance of this disease, since effective control in susceptible varieties will switch back to triazole fungicides. During the three years of this study, QoI resistance to powdery mildew was increasing. This appropriate dose research was therefore a good opportunity to observe the decline in activity under field conditions. Table 6 shows details of the current status and potential future risk of fungicide resistance for the fungicides used in this study.

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

Mode of action	Target site and code	Group name	Chemical group	Common name	Trade name	Comments
C: Respiration	C2: Complex II; succinate-dehydrogenase	Carboxamides		boscalid	Component of Tracker (HGCA8)	Resistance known for specific fungi. Target site mutation H257L. Medium risk. Resistance management required if used for risky pathogens
	C3: Complex III cytochrome c1 (ubiquinol oxidase at Qo site)	QoI fungicides (Quinone outside Inhibitors)	methoxy-acrelates	azoxystrobin picoxystrobin	Amistar Acanto	Resistance known in various fungal species. Target site mutations G143A, F129L and additional mechanisms. Cross resistance shown between all members of the QoI group. **High Risk of resistance**
			methoxy-carbamates	pyraclostrobin	Vivid	
			oximino acetates	kresoxim methyl trifloxystrobin	Component of Landmark Twist/Swift	
			oximino-cetamides	metominostrobin		
			oxazolodine-diones	famoxadone	Component of Charisma	
			dihydro-dioxanines	fluoxastrobin	Component of Fandango	
			imidazolinones	fenamidone		
	Unknown	Unknown		metrafenone	Flexity	**Resistance risk unknown but assumed to be medium to high.**
D amino acids and protein synthesis	D1 methionine biosynthesis (proposed)	AP- fungicides (Anilino Pyrimidines)		cyprodinil	Unix	Resistance known in botrytis and sporadically in Venturia, mechanism speculative **Medium risk of resistance**

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

Mode of action	Target site and code	Group name	Chemical group	Common name	Trade name	Comments
E: signal transduction	E1: G-proteins in early cell signalling (proposed)		quinolines	quinoxyfen	Fortress	Resistance known **Medium risk of resistance**
G: sterol biosynthesis in membranes	G1: C14-demethylase in sterol biosynthesis	DMI fungicides (Demethylation inhibitors)	triazoles	epoxiconazole prothioconazole	Opus Proline	There are great differences in the activity spectra of the different DMI fungicides. Resistance is known in various fungal species. Several resistance mechanisms are known including target site mutation Y136F in cyp 51 gene, ABC transporters and others. Generally wise to accept that cross resistance is present between DMI fungicides active against the same fungus. DMI fungicides are Sterol Biosynthesis Inhibitors (SBIs) but show no cross resistance to other SBI classes. **Medium risk of resistance**
	G2:	Amines (morpholines) SBI Class II	morpholines	fenpropimorph	Corbel	Decreased sensitivity for powdery mildews. Cross resistance within the group generally found but not to other SBI groups. **Low to medium risk of resistance**
			piperidines	fenpropidin	Tern	
			spirketalamines	spiroxamine	Torch	
Multi site activity	Multi site activity		phthalimides	folpet	Folpan	**Low risk of resistance**
			chloronitriles (phthalonitriles)	chlorothalonil	Bravo	**Low risk of resistance**

Table is based on fungicide list compiled by Fungicide Resistance Action Committee (FRAC)

Table 7 Winter barley variety resistance ratings

Variety	Rhynchosporium	Mildew	Yellow rust	Brown rust	Net blotch
Flagon	8	8	7	8	6
Pearl	7	7	5	7	5
Vanessa	8	8	3	3	7
Fanfare	8	6	7	8	7
Saffron	6	5	6	7	8
Spectrum	7	5	7	5	8
Cannock	8	2	8	5	8
Scylla	7	6	6	6	8
Carat	7	7	6	5	7
Haka	5	7	7	7	7
Sumo	5	7	6	8	8
Pastoral	7	2	8	8	7
Regina	7	3	2	8	5
Jewel	8	6	8	6	7
Colossus	8	4	4	3	7
Siberia	8	6	4	5	5
Sequel	8	8	5	5	7
Pict	8	8	6	7	6
Amarena	8	9	4	8	8

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

Table 8 Spring barley variety resistance ratings

Variety	Rhynchosporium	Mildew	Yellow rust	Brown rust	Ramularia
NFC Tipple	5	9	3	9	6
Oxbridge	7	8	4	7	6
Cocktail	7	8	4	8	5
Westminster	8	9	5	5	6
Troon	4	9	8	6	4
Carafe	4	9	3	9	6
Cellar	4	9	4	8	6
Prestige	4	9	4	9	4
Chalice	5	9	7	4	6
Optic	4	5	8	6	6
Decanter	5	9	8	6	8
Waggon	4	9	5	9	6
Tocada	4	6	3	4	7
Wicket	6	7	6	8	6
Power	6	9	6	6	7
Doyen	8	8	3	7	6
Spire	4	6	5	5	5
Rebecca	7	7	3	5	7
Kirsty	5	7	4	9	6
Static	5	9	6	8	6
Riviera	5	8	5	6	6

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

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 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, eradicant activity, yield benefits and impact on green leaf area. This approach is however different to that taken by growers who would look at using 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 field activity is of immediate importance to advisers and growers, since varietal resistance, fungicide resistance and the fungicide products available to growers can change quickly. As such, it is important the information in this research is available quickly and also any changes in efficacy, which may be a result of changes in resistance, are disseminated quickly. 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 is also being developed to allow more direct access to the fungicide dose response curves generated by this research.

Materials and methods

Field trials

Over the three years of trials, a total of 16 winter barley trials were carried out throughout the UK. Three additional spring barley trials funded by TEAGASC and SEERAD were carried out to obtain data on barley leaf spots.

The number of trials for each target disease in this three year study are 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
powdery mildew	1	1	1
rhynchosporium	2	2	2
net blotch	1	2	2
brown rust	1	1	0
ramularia (S barley)	0	1	2
Totals	**5**	**7**	**7**

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
0201	Dumfriesshire	Sumo	rhynchosporium	32	6 May 02
0202	Midlothian	Regina	powdery mildew	32-37	8 May 02
0203	Cornwall	Sumo	rhynchosporium	32	25 Apr 02
0204	East Anglia	Vanessa	brown rust	37-39	2 May 02
0205	East Anglia	Pearl	net blotch	32	25 Apr 02
0301	Dumfriesshire	Sumo	rhynchosporium	32	23 Apr 03
0302	Midlothian	Regina	powdery mildew	49	14 May 03
0303	Cornwall	Sumo	rhynchosporium	39-49	7 May 03
0304	East Anglia	Vanessa	brown rust	39	8 May 03
0305	East Anglia	Pearl	net blotch	32	23 Apr 03
0306	East Anglia	Vanessa	brown rust	39-49	6 May 03
0307	Carlow	Pewter	ramularia	39-45	14 Jun 03
0401	Dumfriesshire	Sumo	rhynchosporium	32-37	2 May 04
0402	Midlothian	Regina	powdery mildew	37	10 May 04
0403	Cornwall	Sumo	rhynchosporium	33	22 Apr 04
0404	East Anglia	Pearl	net blotch	37-39	7 May 04
0405	East Anglia	Pearl	net blotch	37-39	6 May 04
0406	Midlothian	Pewter	ramularia	43-49	16 Jun 04
0407	Carlow	Pewter	ramularia	45-51	16 Jun 04

A detailed protocol (see Annex 1) was developed providing details of the trial layout, fungicide treatments, disease assessments and site details. An untreated control and an epoxiconazole (Opus) fungicide standard were common in all trials. Not all fungicides were tested in the three 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

Unique code	Active ingredient	Product	Rate product/ha	£/ha	Group
1	Epoxiconazole	Opus	2.00 litre	40	NM
2	Epoxiconazole	Opus	1.00 litre	20	NM
3	Epoxiconazole	Opus	0.50 litre	10	NM
4	Epoxiconazole	Opus	0.25 litre	5	NM
5	Fenpropimorph	Corbel	2.00 litre	40	NM
6	Fenpropimorph	Corbel	1.00 litre	20	NM
7	Fenpropimorph	Corbel	0.50 litre	10	NM
8	Fenpropimorph	Corbel	0.25 litre	5	NM
9	Cyprodinil	Unix	1.34 kg	28	N
10	Cyprodinil	Unix	0.67kg	14	N
11	Cyprodinil	Unix	0.335 kg	7	N
12	Cyprodinil	Unix	0.168 kg	4	N
13	Trifloxystrobin	Twist EC	4.00 litre	60	S
14	Trifloxystrobin	Twist EC	2.00 litre	30	S
15	Trifloxystrobin	Twist EC	1.00 litre	15	S
16	Trifloxystrobin	Twist EC	0.50 litre	8	S
17	Picoxystrobin	Acanto	2.00 litre	60	S
18	Picoxystrobin	Acanto	1.00 litre	30	S
19	Picoxystrobin	Acanto	0.50 litre	15	S
20	Picoxystrobin	Acanto	0.25 litre	8	S
21	Pyraclostrobin	Vivid	2.00 litre	64	S
22	Pyraclostrobin	Vivid	1.00 litre	32	S
23	Pyraclostrobin	Vivid	0.50 litre	16	S
24	Pyraclostrobin	Vivid	0.25 litre	8	S
25	HGCA3	Bayer UK756 (Proline)	1.60 litre	50	NM
26	HGCA3	Bayer UK756(Proline)	0.80 litre	25	NM
27	HGCA3	Bayer UK756(Proline)	0.40 litre	13	NM
28	HGCA3	Bayer UK756(Proline)	0.20 litre	6	NM
29	HGCA4	UK958 (Fandango)	2.50 litres	80	M
30	HGCA4	UK958 (Fandango)	1.25 litres	40	M
31	HGCA4	UK958 (Fandango)	0.625 litre	20	M
32	HGCA4	UK958 (Fandango)	0.3125 litres	10	M
33	Untreated	---	---	0	SNM
34	Untreated	---	---	0	SNM
35	Untreated	----	---	0	SNM
36	Untreated	----	---	0	SNM
37	Quinoxyfen	Fortress	0.60 litre	36	NM
38	Quinoxyfen	Fortress	0.30 litre	18	NM
39	Quinoxyfen	Fortress	0.15 litre	9	NM
40	Quinoxyfen	Fortress	0.075 litre	5	NM
41	Spiroxamine	Neon	3.00 litre	44	N
42	Spiroxamine	Neon	1.50 litre	22	N
43	Spiroxamine	Neon	0.75 litre	11	N
44	Spiroxamine	Neon	0.375 litre	6	N

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

Unique code	Active ingredient	Product	Rate product/ha	£/ha	Group
45	Azoxystrobin	Amistar	2.00 litre	56	S
46	Azoxystrobin	Amistar	1.00 litre	28	S
47	Azoxystrobin	Amistar	0.50 litre	14	S
48	Azoxystrobin	Amistar	0.25 litre	7	S
49	HGCA5	BAS560 + Corbel (Flexity + Corbel)	BAS560 1.0 l/ha + Corbel 1.08 l/ha	40	M
50	HGCA5	BAS560 + Corbel (Flexity + Corbel)	BAS560 0.5 l/ha + Corbel 0.54 l/ha	20	M
51	HGCA5	BAS560 + Corbel (Flexity + Corbel)	BAS560 0.25 l/ha + Corbel 0.27 l/ha	10	M
52	HGCA5	BAS560 + Corbel (Flexity + Corbel)	BAS560 0.125 l/ha + Corbel 0.135 l/ha	5	M
53	Trifloxystrobin	Twist SC (Swift)	1.0	60	S
54	Trifloxystrobin	Twist SC (Swift)	0.5	30	S
55	Trifloxystrobin	Twist SC (Swift)	0.25	15	S
56	Trifloxystrobin	Twist SC (Swift)	0.125	8	S
57	Chlorothalonil	Bravo 500	4.0 l/ha	16	N
58	Chlorothalonil	Bravo 500	2.0 l/ha	8	N
59	Chlorothalonil	Bravo 500	1.0 l/ha	4	N
60	Chlorothalonil	Bravo 500	0.5 l/ha	2	N
61	HGCA6	BAS564	3.0 litres	40	M
62	HGCA6	BAS564	1.5 litres	20	M
63	HGCA6	BAS564	0.75 litre	10	M
64	HGCA6	BAS564	0.375 litres	5	M
65	HGCA8	BAS549 (Tracker)	3.0 litres	80	M
66	HGCA8	BAS549 (Tracker)	1.5 litres	40	M
67	HGCA8	BAS549 (Tracker)	0.75 litre	20	M
68	HGCA8	BAS549 (Tracker)	0.375 litres	10	M

Fungicide costs (£/ha) were based on 2004 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.

Fungicides were split into groups for use in summary graphs, which were produced for presentations and Technical notes as: -

S = Strobilurin fungicide

N = Non Strobilurin fungicide

M= Fungicide co-formulations and individual components.

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 fungicide 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 2003 and 2004 for the production of technical notes (see Appendix 3 for the latest note). 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 can be run quickly and easily. The emerging requirements have caused programs to be developed further each year. 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 inputted, 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 sixteen 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 plus 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 three spring barley trials were respectively; 3 replicates of 4 fungicides by 4 levels + 1 untreated control (per replicate); 4 replicates (3 harvested) of 5 fungicides by 4 levels + 4 untreated controls (per replicate); and 4 replicates (3 used for disease assessment) of 5 fungicides by 4 levels + 4 untreated controls (per replicate).

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 (7^{th} 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 both 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

EXCEL "data" files for each of the summaries were compiled from the "results" from the relevant individual trials.

For winter barley the year's trials and the accumulated trials were summarised at the end of each year. Thus in 2002 the data was summarised for 2002; in 2003 for 2003 and for 2002 + 2003; and in 2004 for 2004 and for 2002 + 2003 + 2004.

For spring barley in 2004, a summary of the 3 trials (1 from 2003 and 2 from 2004) was produced. There were insufficient trials in either year to make annual summaries meaningful.

The financial variables "output" and the "margin" were added using 2004 grain prices. The formulae used were:

Output (£ per ha) = Yield (t/ha)*(70 +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.

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 were 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 yearly 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 2004 cumulative analysis allowed a more complicated model to be fitted with fixed effects:

Year + Target Disease by (fungicide by level + untreated control).

Trials were regarded as a random effect in addition to the residual variation. After taking out the effects of year and of target disease there were still large differences between trials and so regarding trials as a fixed effect was an acceptable approximation when there was only a small number of trials. There was little statistical evidence of an interaction between fungicide and target disease. In part this was because the fungicides used varied with the target disease and thus the overlap was small. The yield data were divided by target disease and each part was separately analysed using the simple model with trial as a fixed effect.

Spring Barley

The simple model was fitted to the data.

Transformations

Disease and green leaf data were transformed for the over trials analysis using a 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.

The transformed means were grouped using the Residual Mean Square (RMS) from the over-trials analysis and the counts of trials contributing to each of these means. An approximate standard error of each difference was calculated using the RMS and counts. A Student's t-value was then calculated for each pairwise difference. The formula used for the comparison of fungicides i and j was:

$t_{ij} = (m_i – m_j)/ \text{sqrt} (RMS*(1 / n_i +1 / n_j)$

where m_i and n_i were the mean and counts for the i^{th}fungicide. A t-value of more than 2.00 (or less than –2.00) corresponding to a p value of 0.05, was used to determine whether or not a pair of fungicides was statistically different. This test used an approximation for the standard error of a difference and 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 three 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

% Disease in untreated	**Comment on Disease severity**
0-1	Very low
1-5	Low
6-10	Moderate
11-20	High
>21	Very high

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

Table 13 Comments on the control are based on the following categories of disease control.

% Control	**Comment**
0 -25%	Poor control
26-50%	Moderate control
51-75%	Good control
76-100%	Excellent control

Rhynchosporium

Table 14 % Rhynchosporium levels in untreated

Year	**% Rhynchosporium in untreated Protection data**	**% Rhynchosporium in untreated Eradication data**	**Relative pressure of disease**
2002	13.39	15.37	High
2003	12.94	20.65	High
2004	20.41	37.65	Very High
2002-04	14.69	23.66	High to Very High

Rhynchosporium levels were high in each of the three years of trials (Table 14).

Table 15 % Rhynchosporium protection at half dose 2002-2004

Fungicide	**2002**	**2003**	**2004**	**2002-04**	**Fungicide type**	**Comments on protection**
Unix	52.07	7.63	44.12	30.80	anilino pyrimidines	Poor in 2003, moderate 2002 & 2004
Corbel	75.28	24.71	-	50.85	morpholine	Variable poor to moderate
Neon	-	55.28	-	66.54	morpholine	Good
Flexity+Corbel	-	30.01	-	47.10	Unknown + morpholine	Moderate
Acanto	64.54	52.33	48.64	54.82	QoI	Good
Twist	70.50	48.97	38.48	51.63	QoI	Good to moderate
Vivid	67.44	55.57	34.28	52.17	QoI	Good (moderate in 2004)
Fortress	-	11.77	-	32.96	quinoline	Poor
Opus	76.73	45.15	66.13	60.59	triazole	Good to moderate
Proline	92.18	70.02	88.42	82.68	triazole	Good to excellent
Tracker	-	14.51	50.73	41.14	triazole + carboxamide	Poor in 2003, moderate in 2004
Fandango	92.68	71.37	85.97	83.66	triazole + QoI	Good to excellent

(- no data. 100% = best protection)

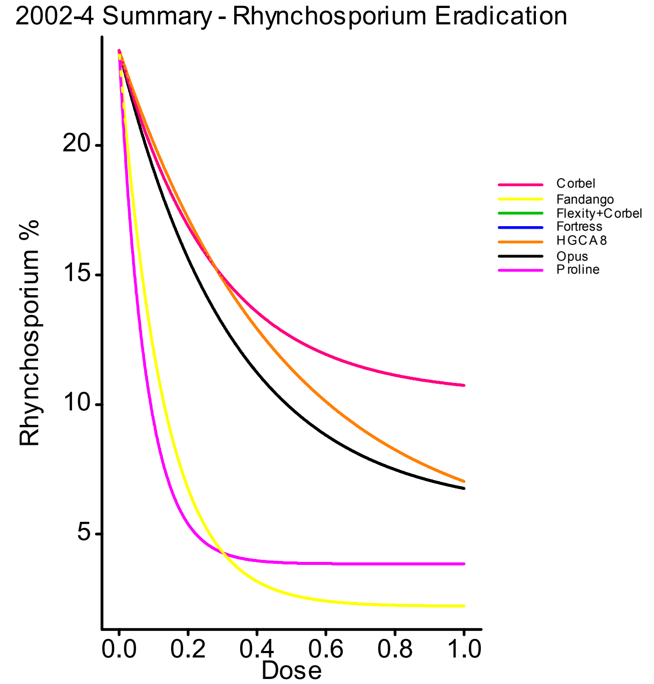
Strobilurins and Opus gave good to moderate protection against rhynchosporium at half dose (Table 15). Disease control was generally lower in 2004, but the disease pressure was also higher making the fungicides work harder. There is currently no evidence to suggest the F129L or the G143A mutation associated with QoI resistance have been detected in rhynchosporium isolates. There is evidence of a decline in activity in epoxiconazole (HGCA Final Report number 315), but it gave consistent control at these trial sites in the west of the country. It is anticipated however, that control may be more unreliable where less sensitive isolates exist. Unix protection was variable, particularly in 2003, but control was moderate in the high pressure 2004 season. Proline and Fandango gave consistently excellent to good control over the three years. There is less data available for Tracker, and the 2004 data is more consistent than 2003. Morpholines gave more variation in their control. This group of fungicides are recognised to be eradicant fungicides, so the poor persistence may be the reason for this variability in protection. Fortress is specific to powdery mildew so rhynchosporium protection was expected to be poor.

Table 16 % Rhynchosporium eradication at half dose 2002-2004

Fungicide	2002	2003	2004	2002-04	Fungicide type	Comment on eradication
Unix	36.39	15.31	25.15	27.03	anilino pyrimidines	Poor to moderate
Corbel	49.36	24.25	-	44.81	morpholine	Moderate
Acanto	57.07	38.58	54.12	51.59	QoI	Good to moderate
Twist	54.02	23.15	25.92	36.12	QoI	Good to poor
Vivid	68.84	57.98	45.01	58.57	QoI	Good to moderate
Opus	57.62	49.27	57.72	56.10	triazole	Good to moderate
Proline	65.12	79.58	90.55	81.72	triazole	Excellent to good
Tracker	-	34.52	54.72	45.50	triazole + carboxamide	Good to moderate
Fandango	71.59	94.45	92.04	87.59	triazole + QoI	Excellent to good

(- no data 100% = best eradication)

Eradicating rhynchosporium is a greater challenge for fungicides. From Table 16 it can be seen that Proline and Fandango achieved the best control, followed by Tracker, Opus and the strobilurin fungicides. There is an indication that Acanto and Vivid gave better eradicative activity than Twist SC. Corbel gave moderate control, but this may be a reflection of its lower persistence than other fungicides. Unix was the weakest at eradicating rhynchosporium.



Order of fungicides at full dose

Corbel

HGCA8 (Tracker)
Opus

Proline
Fandango

Figure 1 Dose curves for rhynchosporium eradication

Figure 1 shows that Fandango and Proline achieved the best control of rhynchosporium at approximately half dose. Opus and HGCA8 (Tracker) achieved similar levels of control. Note the control from Corbel levelled out at 0.4 dose.

Powdery mildew

Table 17 % Powdery mildew levels in untreated

Year	% Powdery mildew in untreated Protection data	% Powdery mildew in untreated Eradication data	Relative pressure of disease
2002	5.38	6.67	Moderate
2003	4.50	6.10	Moderate
2004	8.83	14.83	High
2002-04	6.01	8.56	Moderate

Disease pressure in powdery mildew was higher in 2004 than 2002 and 2003 (Table 17). Care therefore needs to be taken before assuming decline in activity is down to resistance.

Table 18 % Powdery mildew protection at half dose 2002- 2004

Fungicide	2002	2003	2004	2002-04	Fungicide type	Comment on protection
Unix	72.09	29.63	6.48	41.11	anilino pyrimidines	Declining trend poor in 2004
Corbel	27.13	3.70	-	35.04	morpholine	Moderate to poor
Neon	68.99	33.33	35.85	48.16	morpholine	Good to moderate
Flexity+Corbel	92.25	44.44	76.32	76.22	Unknown + morpholine	Excellent, but moderate in 2003
Acanto	81.40	0.00	27.83	45.92	QoI	Excellent in 2002, decline in 2003-04
Fortress	79.84	18.52	42.45	52.70	quinoline	Excellent in 2002, currently moderate
Opus	53.49	29.63	44.34	43.25	triazole	Moderate to poor
Proline	76.74	33.33	65.57	61.85	triazole	Good to moderate

(- no data %100 = best protection)

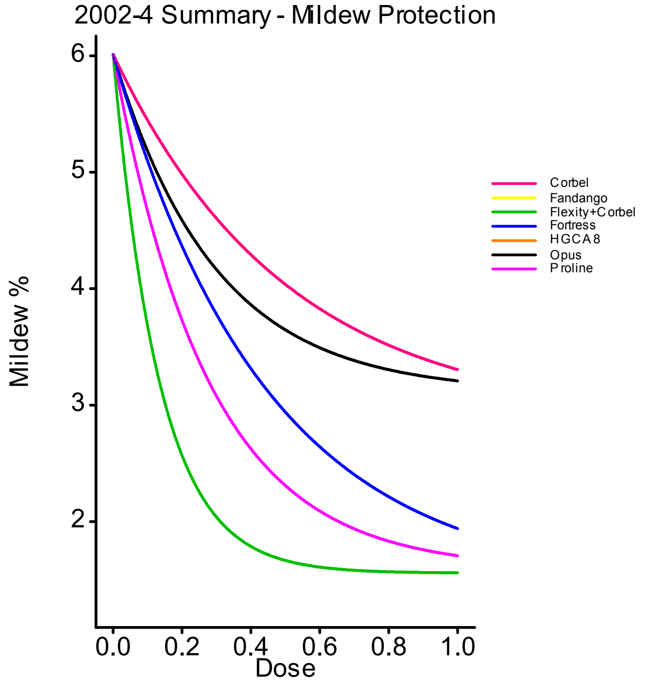
Flexity + Corbel achieved the best protection, alongside Proline and Fortress (Table 18). Note the variation in protection from Acanto. This may be due to a changing QoI resistance situation. Note Corbel achieved lower levels of protection compared to Neon. Unix also gave a useful level of protection.

Table 19 % Powdery mildew eradication at half dose 2002-2004

Fungicide	2002	2003	2004	2002-04	Fungicide type	Comment on protection
Unix	45.00	5.24	19.10	24.70	anilino pyrimidines	Declining, poor in 2004
Corbel	80.00	32.57	30.34	52.48	morpholine	Declining, moderate in 2004
Neon	50.00	39.86	16.85	36.17	morpholine	Declining, poor in 2004
Flexity+Corbel	70.00	45.33	5.62	44.16	Unknown + morpholine	Declining, poor in 2004
Acanto	60.00	13.44	21.35	34.29	QoI	Declining, poor in 2004
Fortress	65.00	31.66	-5.62	34.51	quinoline	Declining, none in 2004
Opus	55.00	48.06	37.08	46.84	triazole	Moderate
Proline	70.00	50.80	39.33	54.42	triazole	Good to moderate (declining)

(Minus value = increase in disease compared to untreated. 100% = best eradication)

Eradication from the triazole fungicide Proline was similar to the morpholine Corbel. Fortress achieved poor eradication, but this fungicide is known to have poor eradicant properties against powdery mildew.



Order of fungicides at full dose

Corbel
Opus

Fortress
Proline
Flexity + Corbel

Figure 2 Dose curves for mildew protection

Flexity + Corbel achieved the best protection (Figure 2). The curve flattened out at approximately half dose. The curve for Fortress and Proline only started to flatten out at 0.8 dose or higher.

Brown rust

Table 20 Brown rust levels in untreated

Year	% Brown rust in untreated Protection data	% Brown rust in untreated Eradication data	Relative pressure of disease
2002	10.83	4.91	High
2003	12.04	3.97	High
2004	4.83	-	Moderate
2002-04	10.06	4.33	Moderate

(- no data)

From Table 20 it can be seen that disease levels were high in 2002 and 2003, but lower in 2004.

Table 21 % Brown rust protection at half dose 2002- 2004

Fungicide	2002	2003	2004	2002-04	Fungicide type	Comment on protection
Unix	68.56	72.96	-17.24	57.24	anilino pyrimidines	Good to poor
Corbel	59.26	24.30	-	33.04	morpholine	Good to poor
Neon	74.27	53.98	-	58.98	morpholine	Good
Acanto	77.10	85.22	80.00	81.93	QoI	Very good
Amistar	78.39	85.43	80.00	82.43	QoI	Very good
Twist	56.75	70.29	42.07	61.20	QoI	Good to moderate
Vivid	79.14	79.56	44.83	75.89	QoI	Excellent, decline in 2004
Opus	82.18	77.62	51.72	76.55	triazole	Excellent to good
Proline	82.93	76.27	65.52	77.41	triazole	Excellent to good
Fandango	87.47	88.83	75.86	86.89	triazole + QoI	Excellent

(- no data. Minus values = increase in disease compared to untreated. 100% = best protection)

Controlling brown rust was straightforward for many fungicides (Table 21). The QoI fungicides gave excellent to good control, with the exception of Twist, which is known to be weaker against brown rust. The triazoles Proline and Opus also gave excellent control. Unix is known to be weak against brown rust and in 2004, gave no control.

Table 22 % Brown rust eradication at half dose 2002-2004

Fungicide	2002	2003	2004	2002-04	Fungicide type	Comment on eradication
Unix	-22.01	71.68	-	35.65	anilino pyrimidines	Variable
Corbel	68.35	81.29	-	77.65	morpholine	Excellent
Neon	92.74	73.94	-	82.40	morpholine	Excellent
Acanto	94.11	81.24	-	87.58	QoI	Excellent
Amistar	78.37	90.66	-	86.12	QoI	Excellent
Twist	14.39	82.70	-	56.46	QoI	Excellent to poor
Vivid	82.95	80.17	-	81.35	QoI	Excellent
Opus	97.65	94.83	-	96.12	triazole	Excellent
Proline	97.57	94.76	-	96.05	triazole	Excellent
Fandango	98.78	98.31	-	98.52	triazole + QoI	Excellent

(- no data. Minus values = increase in disease compared to untreated. 100% = best eradication)

Eradication of brown rust was relatively straightforward with most fungicides (Table 22 and Figure 3). Unix was the exception, but this fungicide is known to give poor control of this disease.

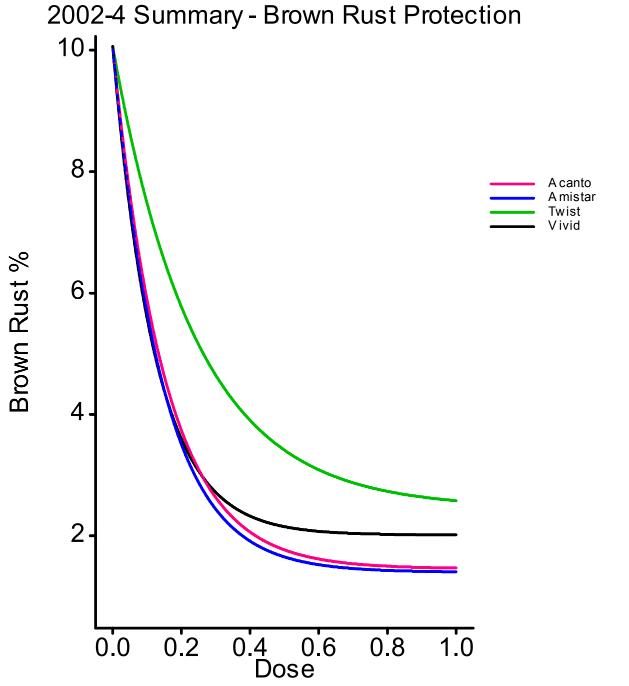
 	**Order of fungicides at full dose** Twist Vivid Acanto Amistar

Figure 3 Dose curves for brown rust

QoI fungicides continue to give good protection against brown rust. Best control was achieved with Amistar and Acanto.

Net blotch

Table 23 Net blotch levels in untreated

Year	% Net blotch in untreated Protection data	% Net blotch in untreated Eradication data	Relative pressure of disease
2002	-	-	Very low
2003	-	-	Very low
2004	5.94	4.38	Moderate

Results were restricted to 2004 since disease levels in 2002 and 2003 were very low (Table 23).

Table 24 % Net blotch protection at half dose 2002- 2004

Fungicide	**2002**	**2003**	**2004**	**Fungicide type**	**Comment on protection**
Unix	-	-	66.34	anilino pyrimidines	Good
Corbel	-	-	19.68	morpholine	Poor
Neon	-	-	38.15	morpholine	Moderate
Acanto	-	-	52.72	QoI	Good
Amistar	-	-	59.04	QoI	Good
Twist	-	-	41.59	QoI	Moderate
Vivid	-	-	67.67	QoI	Good
Opus	-	-	7.79	triazole	Poor
Proline	-	-	25.41	triazole	Moderate to poor
Fandango	-	-	50.77	triazole + QoI	Good

(- no data. 100% = best protection)

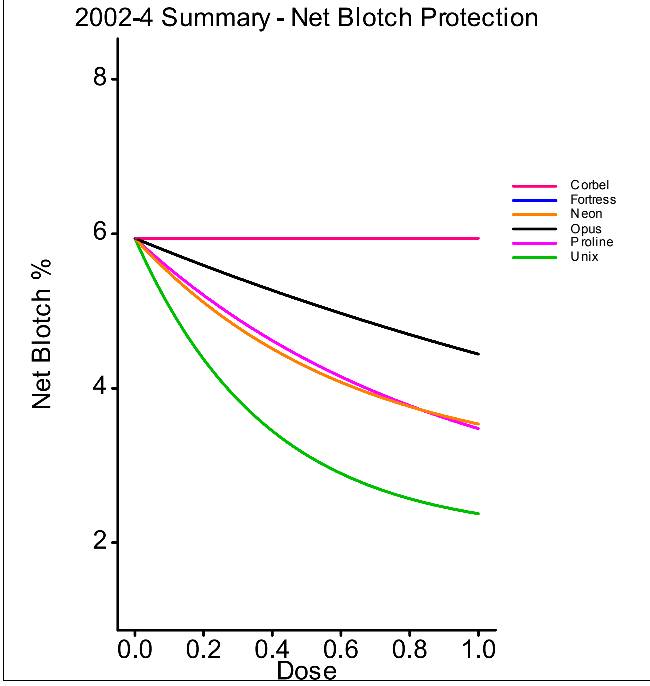
The QoI fungicides gave moderate to good control, suggesting no issues in field performance at the trial sites. Unix also gave good control (Table 24).   The triazoles were weaker, but the co-formulation Fandango which comprises a triazole and strobilurin, achieved good control.

Table 25 % Net blotch eradication at half dose 2002-2004

Fungicide	**2002**	**2003**	**2004**	**Fungicide type**	**Comment on eradication**
Unix	-	-	50.48	anilino pyrimidines	Good to moderate
Acanto	-	-	61.90	QoI	Good
Amistar	-	-	31.43	QoI	Moderate
Twist	-	-	39.05	QoI	Moderate
Vivid	-	-	74.86	QoI	Good
Opus	-	-	27.62	triazole	Moderate
Proline	-	-	67.24	triazole	Good
Fandango	-	-	59.62	triazole + QoI	Good

(- no data. 100% = best eradication)

Table 25 shows that the QoI fungicides gave good eradication, with Acanto and Vivid giving the best control. Proline and Fandango also gave good eradication, whilst Unix gave good to moderate control.



Order of fungicides at full dose

Corbel

Opus

Neon
Proline

Unix

Figure 4 Dose curves for net blotch protection

Although the disease levels are low in the average data, it shows useful protection was achieved with Unix (Figure 4). It is worth noting the difference between Corbel and Neon.

Ramularia (Spring barley)

Three spring barley trials were carried out in 2002-2003. Results are reported as a mean of all three sites. Due to the nature of leaf spots, results are for disease protection only (Table 26).

Table 26 Ramularia levels in untreated

Year	% Ramularia in untreated Protection data	Relative pressure of disease
2002-03	7.6	Moderate

Table 27 % Ramularia protection at range of doses 2003- 2004

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Fungicide type**	**Comment on control at half dose**
Bravo_500	41.23	73.94	82.99	85.56	multisite	Excellent
Acanto	-42.90	19.32	15.38	-33.01	QoI	Poor
Vivid	-27.07	29.62	-15.41	23.07	QoI	Moderate
Opus	22.17	59.54	63.34	75.59	triazole	Good
Proline	37.69	64.27	79.16	85.74	triazole	Good
Fandango	37.47	53.57	57.90	62.00	triazole + QoI	Good

(Minus value = more disease than untreated. 100% = best protection)

QoI fungicides were the least effective in controlling ramularia (Table 27). Bravo achieved the best control whilst the triazole fungicides and Fandango achieved good control.

Abiotic leaf spots (spring barley)

Three spring barley trials were carried out in 2002-2003. Results are reported as a mean of all three sites (Table 28). Due to the nature of the development of leaf spots, results are for disease protection only.

Table 28 Abiotic leaf spots levels in untreated

Year	% Abiotic leaf spots in untreated Protection data	Relative pressure of disease
2003-04	24.2	Very High

Table 29 % Abiotic leaf spots protection at range of doses 2003- 2004

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Fungicide type**	**Comment on control at half dose**
Bravo_500	31.96	59.30	67.75	76.60	multisite	Good
Acanto	-8.92	-18.92	-8.78	-21.65	QoI	Negative
Vivid	13.18	33.14	21.71	43.56	QoI	Moderate
Opus	29.11	54.58	40.58	66.17	triazole	Good
Proline	35.20	62.23	80.14	81.53	triazole	Good
Fandango	54.05	48.86	74.11	68.25	triazole + QoI	Moderate

(Minus value = more disease than untreated. 100% = best protection)

Bravo and the triazole fungicides achieved the best reduction (Table 29). Strobilurin fungicides were more variable, with Acanto giving higher levels of abiotic leaf spots at half dose.

Determining significant differences between the fungicides.

Tables 30 and 31 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.

If there was a marked change in the efficacy of a fungicide over the three years, this would become averaged in these tables.

Table 30 Rhynchosporium protection and eradication at half dose 2002-2004

	Rhynchosporium protection			Rhynchosporium eradication			
Fungicide	**% Disease**	**Significance**	**Number of trials**	**% Disease**	**Significance**	**Number of trials**	**Fungicide type**
Unix	10.2	c	8	17.3	b	6	anilino pyrimidines
Corbel	7.22	bc	5	13.1	b	4	morpholine
Acanto	6.64	bc	8	11.5	b	6	QoI
Twist	7.11	bc	7	15.1	b	6	QoI
Vivid	7.03	bc	7	9.81	b	6	QoI
Opus	5.79	b	8	10.4	b	6	triazole
Proline	2.54	a	8	4.33	a	6	triazole
Tracker	8.65	bc	3	12.9	b	3	triazole + carboxamide
Fandango	2.4	a	6	2.94	a	5	triazole + QoI

At half dose, Fandango and Proline achieved the best reduction in disease and gave a significant reduction in disease over the other fungicides (Table 30). Opus gave the next level of control. The strobilurin fungicides Vivid, Acanto and Twist, plus Tracker achieved an intermediate level of control, whilst Unix and Corbel achieved the lowest level of control.

Table 31 Mildew protection and eradication at half dose 2002-2004

	Mildew protection			Mildew eradication			
Fungicide	**% Disease**	**Significance**	**Number of trials**	**% Disease**	**Significance**	**Number of trials**	**Fungicide type**
Unix	3.54	b	3	6.45	b	3	anilino pyrimidines
Corbel	3.9	b	3	4.07	a	3	morpholine
Neon	3.12	b	3	5.46	ab	3	morpholine
Flexity+Corbel	1.43	a	3	4.78	ab	3	Unknown + morpholine
Acanto	3.25	b	3	5.62	ab	3	QoI
Fortress	2.84	b	3	5.61	ab	3	quinoline
Opus	3.41	b	3	4.55	ab	3	triazole
Proline	2.29	ab	3	3.90	a	3	triazole

Flexity + Corbel achieved the best protection and was significantly better than the other fungicides (Table 31). Proline gave the next level of protection, followed by all the other products. For eradication, Corbel and Proline achieved the best control, whilst Unix was the least effective.

Table 32 Brown rust protection and eradication at half dose 2002-2004

	Brown rust protection			Brown rust eradication			
Fungicide	**% Disease**	**Significance**	**Number of trials**	**% Disease**	**Significance**	**Number of trials**	**Fungicide type**
Unix	4.30	bc	3.00	2.79	e	2	anilino pyrimidines
Corbel	6.74	c	3.00	0.97	cd	3	morpholine
Neon	4.13	bc	3.00	0.76	cd	3	morpholine
Acanto	1.82	a	6.00	0.54	bc	5	QoI
Amistar	1.77	a	6.00	0.60	bc	5	QoI
Twist	3.90	bc	3.00	1.89	de	2	QoI
Vivid	2.43	ab	6.00	0.81	cd	5	QoI
Opus	2.36	ab	6.00	0.17	ab	5	triazole
Proline	2.27	a	6.00	0.17	ab	5	triazole
Fandango	1.32	a	6.00	0.06	a	5	triazole + QoI

Fandango, Proline, Amistar and Acanto achieved the best protection, whilst Corbel was the least effective. For eradication, Fandango achieved the best control, whilst Unix was the least effective (Table 32).

Table 33 Net blotch protection and eradication at half dose 2004

	Net blotch protection			Net blotch eradication			
Fungicide	**% Disease**	**Significance**	**Number of trials**	**% Disease**	**Significance**	**Number of trials**	**Fungicide type**
Unix	2.00	ab	1.00	2.17	-	1	anilino pyrimidines
Corbel	4.77	bc	1.00	-	-	-	morpholine
Neon	3.67	abc	1.00	-	-	-	morpholine
Acanto	2.81	abc	2.00	1.67	-	1	QoI
Amistar	2.43	ab	2.00	3.00	-	1	QoI
Twist	3.47	abc	1.00	2.67	-	1	QoI
Vivid	1.92	a	2.00	1.10	-	1	QoI
Opus	5.48	c	2.00	3.17	-	1	triazole
Proline	4.43	bc	2.00	1.43	-	1	triazole
Fandango	2.92	abc	2.00	1.77	-	1	triazole + QoI

(- no data)

Vivid achieved the best protection, whilst Opus was the least effective. Note however the average levels of disease were low (Table 33).

Table 34 Ramularia and abiotic leaf spots protection and eradication at half dose 2003-2004 in spring barley

	Ramularia protection			Abiotic leaf spots protection		
Fungicide	**% Disease**	**Significance**	**Number of trials**	**% Disease**	**Significance**	**Number of trials**
Proline	2.73	a	3	9.14	a	3
Bravo_500	1.99	a	3	9.85	a	3
Opus	3.09	a	3	11.00	a	3
Fandango	3.55	a	2	12.38	a	2
Vivid	5.38	a	2	16.19	ab	2
Acanto	6.16	a	1	28.79	b	1

Proline and Bravo achieved the best protection in ramularia and abiotic leaf spots. Acanto was the least effective at reducing abiotic leaf spots (Table 34 and Figures 5 – 8).

Figure 5 Dose curves for ramularia (co-formulations and standards)

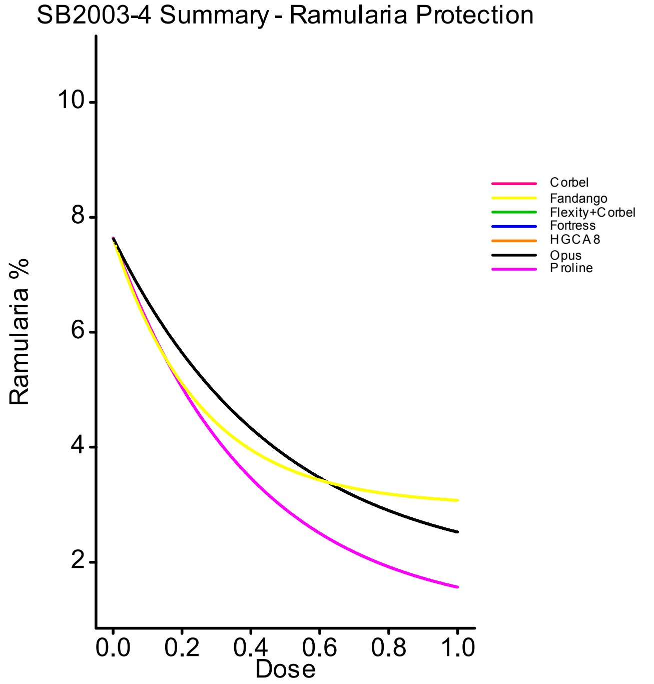
	**Order of fungicides at full dose** Fandango Opus Proline

Figure 6 Dose curves for ramularia (QoI fungicides)

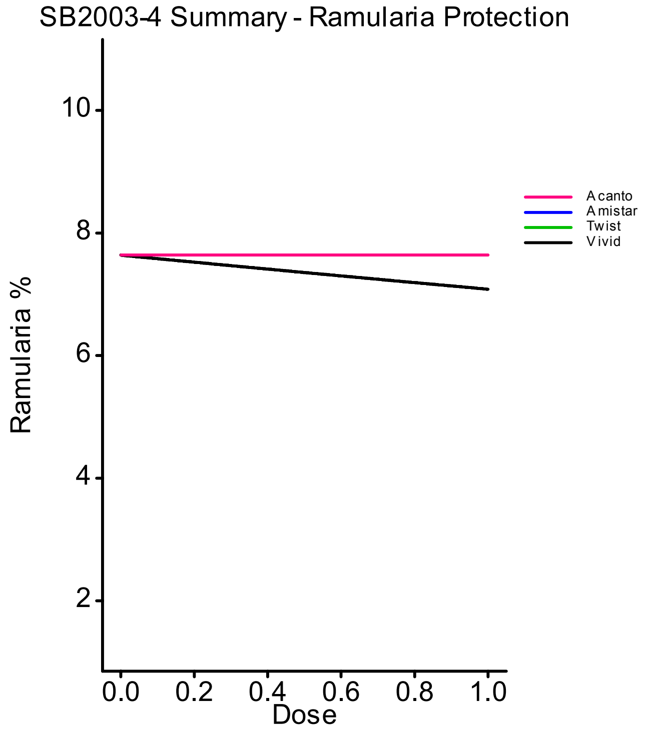
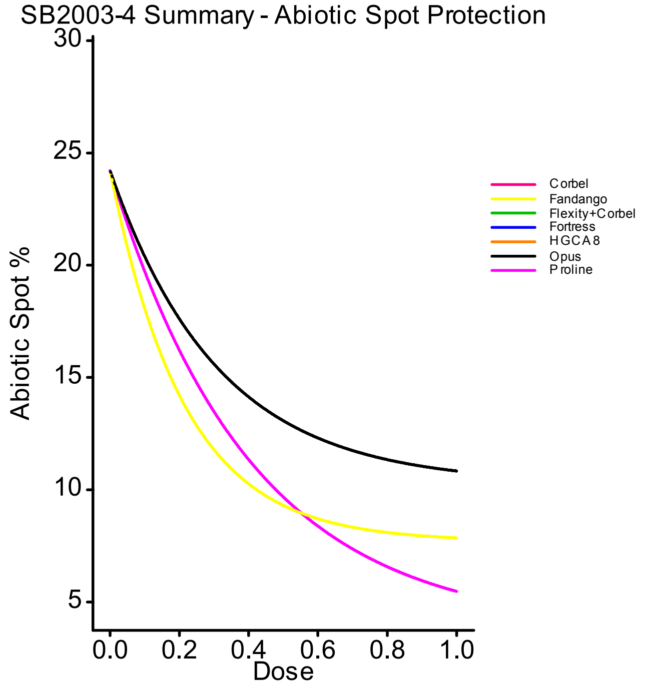
	**Order of fungicides at full dose** Acanto Vivid

Figure 7 Dose curves for abiotic spots (co-formulations & standards)



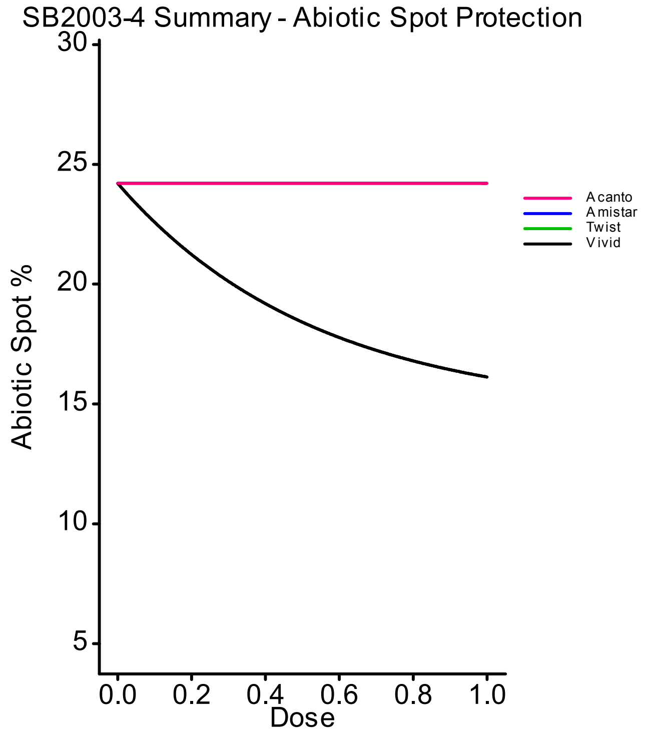
Order of fungicides at full dose

Opus

Fandango

Proline

Figure 8 Dose curves for abiotic spots (QoI fungicides)



Order of fungicides at full dose

Acanto

Vivid

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 35 provides a definition of the yield responses given in these tables, whilst Tables 36, 37 and 38 shows the fungicide responses relating to the untreated control in each of the three years.

Table 35 Categories for comments on the yield responses to fungicide

Yield response T/ha over untreated control	Comment
-0.25 – 0 t/ha	Negative
0	None
0.1-0.25	Slight
0.26-0.5	Moderate
0.51-1.0	High
>1.0	Very High

Table 36 Yield response in tonnes/hectare to fungicides in 2002

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Yield response to fungicide (0.5 dose)**	**Fungicide type**
Nil 6.29 t/ha	-	-	-	-	*	*
Unix	0.17	0.26	0.40	0.53	Moderate	anilino pyrimidines
Corbel	0.22	0.26	0.39	0.50	Moderate	morpholine
Neon	0.58	0.11	0.74	0.00	Slight	morpholine
Flexity+Corbel	0.28	0.49	0.41	0.75	Moderate	Unknown + morpholine
Twist	0.20	0.56	0.70	0.78	High	QoI
Acanto	0.37	0.45	0.61	0.95	Moderate	QoI
Vivid	0.43	0.62	0.74	1.13	High	QoI
Amistar	0.74	0.41	0.99	1.38	Moderate	QoI
Fortress	-0.10	0.50	0.25	0.34	Slight	quinoline
Opus	0.45	0.47	0.59	0.93	Moderate	triazole
Proline	0.76	0.74	0.95	1.17	High	triazole
Fandango	0.95	1.11	1.01	1.32	Very high	triazole + QoI

In 2002, the best yields were achieved with Fandango, Proline and Vivid. The majority achieved moderate yield responses in the 0.25 – 0.5 t/ha category, with the morpholines, quinoline and anilino pyrimidines giving the lowest yield response (Table 36).

Table 37 Yield response in tonnes/hectare to fungicides in 2003

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Yield response to fungicide (0.5 dose)**	**Fungicide type**
Nil 6.65 t/ha	-	-	-	-	*	*
Unix	0.18	0.40	0.39	0.81	Moderate	anilino pyrimidines
Corbel	0.19	0.03	0.55	0.48	High	morpholine
Neon	0.27	0.41	0.50	0.76	Moderate	morpholine
Flexity+Corbel	0.78	0.43	0.33	0.56	Moderate	Unknown + morpholine
Acanto	0.29	0.62	0.91	1.09	High	QoI
Vivid	0.54	0.68	0.86	1.03	High	QoI
Amistar	0.65	0.50	1.05	1.01	Moderate	QoI
Twist_SC	0.49	0.70	0.68	1.12	High	QoI
Fortress	0.57	0.18	0.47	0.09	Slight	quinoline
Opus	0.49	0.60	0.72	0.86	High	triazole
Proline	0.65	0.90	0.89	1.41	High	triazole
Tracker	0.81	0.98	1.09	1.52	High	triazole + carboxamide
Fandango	0.94	1.04	1.17	1.43	Very High	triazole + QoI

In 2003, Fandango, the QoI fungicides and the triazole fungicides achieved the best yields. The quinoline fungicide Fortress achieved the lowest yield response (Table 37).

Table 38 Yield response in tonnes/hectare to fungicides in 2004

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Yield response to fungicide (0.5 dose)**	**Fungicide type**
Nil 5.75t/ha	-	-	-	-	*	*
Unix	0.28	0.41	0.49	1.01	Moderate	anilino pyrimidines
Corbel	0.44	0.19	0.58	0.62	Slight	morpholine
Neon	0.35	0.68	0.62	1.05	High	morpholine
Flexity+Corbel	0.70	1.00	1.03	1.25	High	Unknown + morpholine
Acanto	0.52	0.86	0.92	0.98	High	QoI
Vivid	0.49	0.74	0.99	0.75	High	QoI
Amistar	0.73	0.87	0.71	0.80	High	QoI
Twist_SC	0.54	0.68	0.81	0.99	High	QoI
Fortress	0.78	-0.03	0.34	0.64	Negative	quinoline
Opus	0.33	0.44	0.67	0.80	Moderate	triazole
Proline	0.78	0.89	0.84	1.42	High	triazole
Tracker	0.77	0.79	0.93	1.12	High	triazole + carboxamide
Fandango	0.65	0.97	1.04	1.27	High	triazole + QoI

In 2004, QoI, triazole fungicides and Fandango continued to achieve the best yields. The quinoline fungicide Fortress achieved a lower yield benefit (Table 38).

Table 39 summarises the yield responses over the three years for each fungicide group.

Table 39 Average yields 2002-04

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Yield response to fungicide at half dose**	**Fungicide type**
Nil 6.27t/ha	-	-	-	-	*	*
Unix	6.47	6.62	6.69	7.05	Moderate	anilino pyrimidines
Corbel	6.51	6.41	6.76	6.78	Slight	morpholine
Neon	6.64	6.66	6.86	6.89	Moderate	morpholine
Flexity+Corbel	6.85	6.90	6.85	7.11	High	Unknown + morpholine
Acanto	6.65	6.91	7.09	7.28	High	QoI
Vivid	6.75	6.95	7.13	7.24	High	QoI
Amistar	6.96	6.84	7.20	7.32	High	QoI
Twist_SC	6.68	6.91	7.00	7.23	High	QoI
Fortress	6.68	6.48	6.62	6.62	Slight	quinoline
Opus	6.69	6.78	6.93	7.13	High	triazole
Proline	6.99	7.11	7.16	7.60	High	triazole
Tracker	7.03	7.10	7.23	7.50	High	triazole + carboxamide
Fandango	7.11	7.31	7.34	7.61	Very High	triazole + QoI

Table 40 focuses on the half dose treatments and shows the yields in increasing order and their significance. This includes data from all the winter barley trials.

Table 40 Yields at half the label dose (average 2002-04)

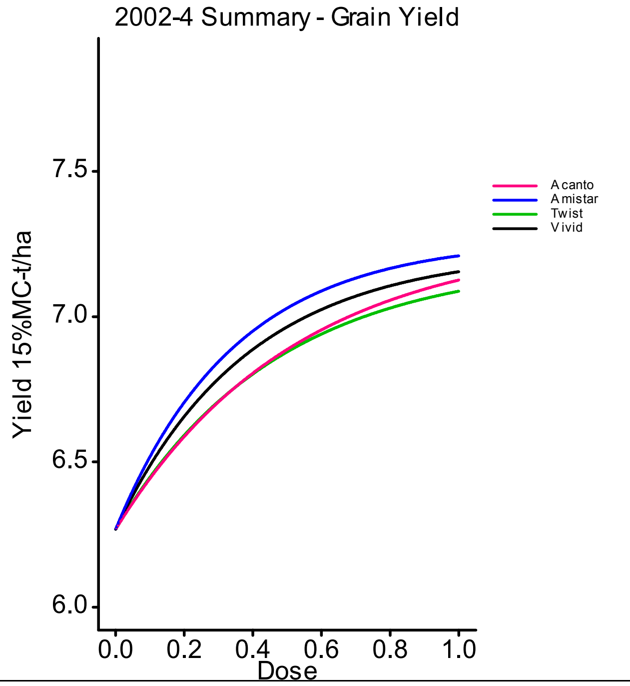
Best yield

	T/ha at half dose	**Significance**	**Number of trials Counts**	**Fungicide type**
Fandango	7.31	a	16	triazole + QoI
Proline	7.11	ab	16	triazole
Tracker	7.10	ab	3	triazole + carboxamide
Vivid	6.95	b	13	QoI
Acanto	6.91	bc	16	QoI
Twist	6.91	bc	9	QoI
Flexity+Corbel	6.90	bcd	3	Unknown + morpholine
Amistar	6.84	bcd	7	QoI
Opus	6.78	bcde	16	triazole
Neon	6.66	cde	7	morpholine
Unix	6.62	de	12	anilino pyrimidines
Fortress	6.48	de	3	quinoline
Corbel	6.41	e	11	morpholine
Untreated	6.27	-	-	

Lowest yield

Fandango achieved the best yield overall alongside Proline and HGCA8 (Tracker). Fandango achieved a significantly better yield than all fungicides with the exception of Tracker and Proline. The strobilurin fungicides, Flexity + Corbel and Opus were amongst the next highest yielding treatments, followed by Neon, Unix, Fortress and Corbel.

Figures 9, 10 and 11 yields for each of the fungicides following curve fitting. This provides a visual way of understanding the yield response to each of the fungicides.

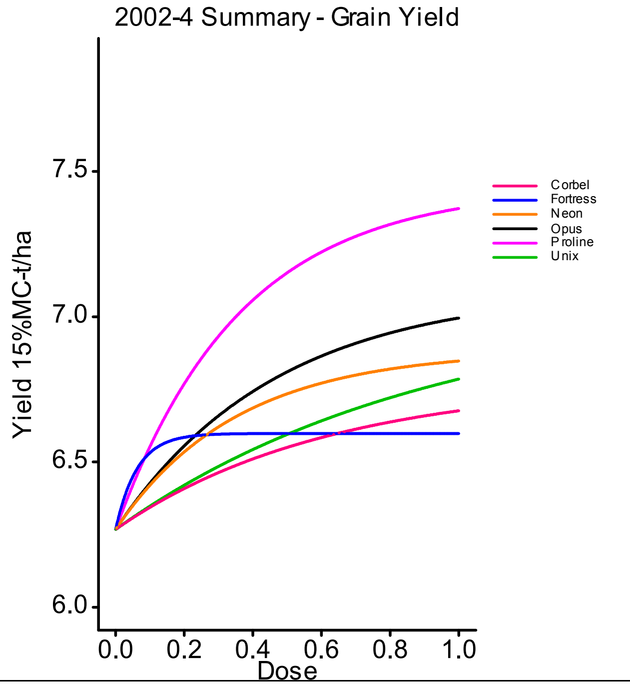


Order of fungicides at full dose

Amistar
Vivid
Acanto
Twist

Figure 9 Yield response for QoI fungicides in winter barley

All the QoI fungicides followed the same pattern in yield response and Table 37 shows that at half dose, there were no significant differences between the fungicides. The curves suggest that as dose increases, yield response also increases. The curve starts to flatten out at approximately 0.8 dose.



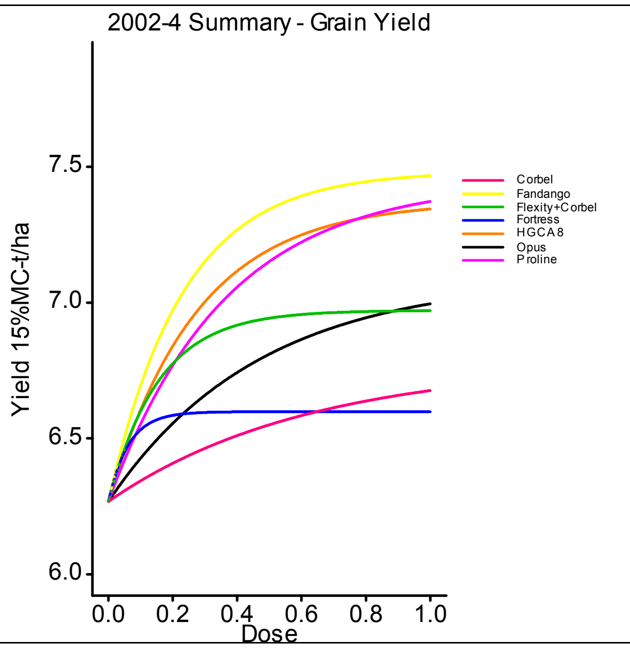
Order of fungicides at full dose

Proline

Opus
Neon
Unix
Corbel
Fortress

Figure 10 Yield response to non QoI fungicides in winter barley

Proline achieved the best yield and from the data in Table 37, this was significantly higher than the yield achieved from the next best yielder on this graph (Opus) or any of the other fungicides on the graph. With the exception of Fortress, the yield of all the fungicides increase with dose. Note with Unix, the dose increase was linear. Many of the others tended to start to flatten out at approximately 0.8 dose. Fortress achieved the best yield at 0.25 dose, but the yield was the lowest of all the fungicides listed in the figure.



Order of fungicides at full dose

Fandango
Proline
HGCA8 (Tracker)
Opus
Flexity + Corbel

Corbel
Fortress

Figure 11 Yield response to co-formulations and standards in winter barley

Co-formulations and fungicide mixtures are expected to be amongst the higher yielding products, since the two active ingredients are likely to complement each other in disease control and yield. There is also likely to be a higher level of active ingredient at any specific dose compared to a single product. Note the yield difference between Fandango (2 actives) and Proline (1 active) is smaller than that between HGCA8 (Tracker2 actives) and Opus (1 active) or between Flexity + Corbel (2 actives) and Corbel (1 active).

The yield data was split into three groups depending upon the dominant disease, mildew rhynchosporium and brown rust (Table 41).

Table 41 Yield benefits where the major disease was rhynchosporium, brown rust or mildew

Fungicide	Rhynchosporium yields at half dose			Brown rust yields at half dose			Mildew rust yields at half dose		
	T/ha	**Significance**	**Trial No**	**T/ha**	**Significance**	**Trial No**	**T/ha**	**Significance**	**Trial No**
Corbel	5.65	d	4	6.89	e	4	6.67	bc	3
Unix	5.80	cd	6	7.08	de	3	6.82	bc	3
Opus	5.83	cd	6	7.52	bcd	7	6.95	abc	3
Acanto	5.84	cd	6	7.85	ab	7	6.86	abc	3
Vivid	5.90	bcd	6	7.81	ab	7	-	-	-
Twist	5.99	bc	6	7.71	abc	3	-	-	-
HGCA8 (Tracker)	6.23	ab	3	-	-	-	-	-	-
Proline	6.33	a	6	7.72	abc	7	7.25	a	3
Fandango	6.48	a	5	7.99	a	7	-	-	-
Neon	-	-	-	7.36	cd	4	6.79	bc	3
Amistar	-	-	-	7.56	bc	7	-	-	-
Fortress	-	-	-	-	-	-	6.56	c	3
Flexity+Corbel	-	-	-	-	-	-	6.98	ab	3

- no data

Where powdery mildew was the dominant disease, Proline achieved the best yield, followed by Flexity + Corbel and Opus. Fortress and Corbel were the lowest yielding treatments.

Where rhynchosporium was the dominant disease, Fandango and Proline achieved the best yields, whilst Corbel achieved the lowest yield.

Where brown rust was the dominant disease, Acanto and Fandango achieved the best yield. Corbel gave the lowest yield. Note Proline was no longer the top yielding where brown rust dominates.

The yield difference between the untreated and the most responsive fungicide was 0.85 T/ha for powdery mildew, 1.09 t/ha for rhynchosporium and 1.03 t/ha for brown rust.

Table 42 Yield response summary from different fungicide groups

Fungicide group	Yield response
triazole + QoI	Very High to High
triazole + carboxamide	High
Unknown + morpholine	High to Moderate
QoI	High to Moderate
triazole	High to Moderate
anilino pyrimidines	Moderate
morpholine	High to slight
quinoline	Moderate to Negative

Over the three years trials, Fungicides comprising two modes of action, were at the top of the table. QoI and triazole fungicides were the most responsive single active ingredients, whilst the mildew specific fungicide quinoline achieved the lowest yield response (Table 42).

Spring barley yields

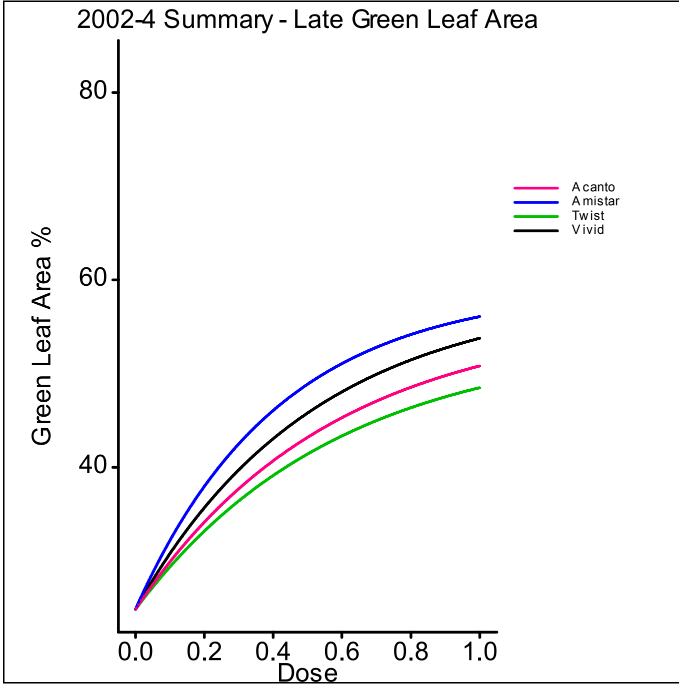
Table 43 shows the fungicide response in the three spring barley trials. Yield responses at the half dose were similar for all fungicides, with the exception of Acanto which gave a negative response at this dose rate.

Table 43 Yield response in spring barley tonnes/hectare to fungicides in 2003-04

	Fungicide dose					
Product label	**0.25**	**0.5**	**1.0**	**2.0**	**Yield response to fungicide (0.5 dose)**	**Fungicide type**
Opus	0.08	0.28	0.46	0.66	Moderate	multisite
Acanto	0.22	-0.09	-0.18	0.07	Negative	QoI
Vivid	0.41	0.42	0.46	0.32	Moderate	QoI
Proline	0.35	0.32	0.68	0.67	Moderate	triazole
Fandango	0.27	0.38	0.65	0.52	Moderate	triazole
Bravo_500	0.25	0.39	0.38	0.58	Moderate	triazole + QoI

Green leaf area and yield

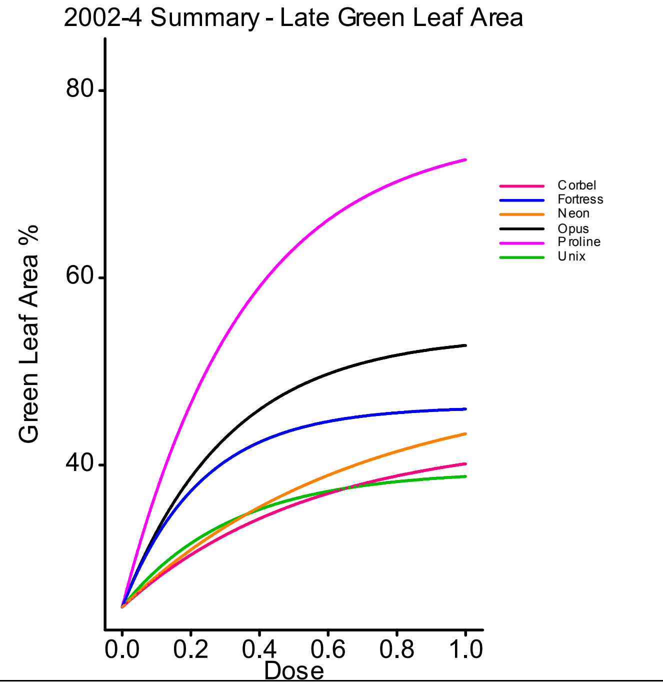
The percentage green leaf area at the later assessments are described in Figures 12, 13 and 14. The QoI fungicides achieved similar green leaf scores to each other which reached an optimum at approximately 0.8 dose. Fandango and Proline achieved the best green leaf area retention maintaining levels at approximately 70-80% green leaf area. HGCA8 (Tracker) and Opus were similar to the strobilurin fungicides. Flexity + Corbel gave a different curve, achieving good green leaf area retention at a third dose, but achieving no better green leaf area retention at a higher dose rate. Fortress, the morpholines Corbel and Neon and the anilino pyrimidines product Unix achieved the lowest green leaf area retention scores (Table 44 and Figure 15).



Order of fungicides at full dose

Amistar
Vivid
Acanto
Twist

Figure 12 Green leaf area retention in winter barley for QoI fungicides

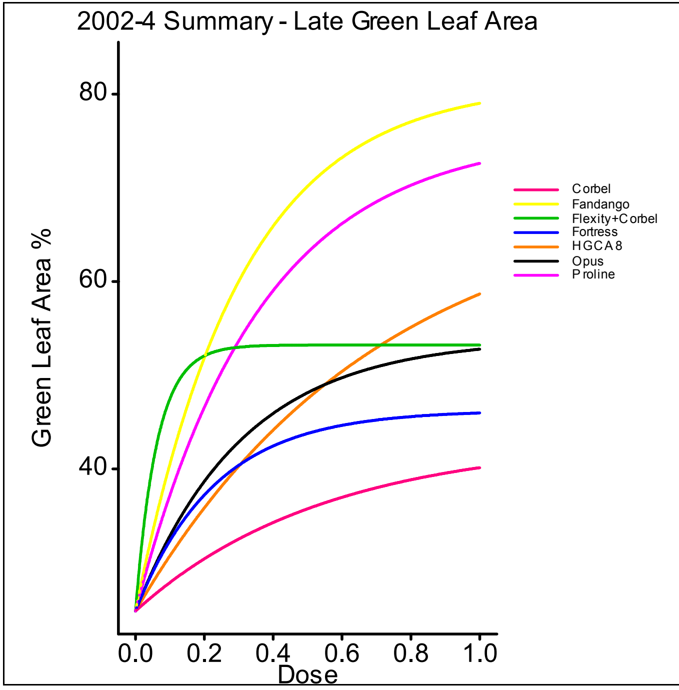


Order of fungicides at full dose

Proline

Opus
Fortress
Neon
Corbel
Unix

Figure 13 Green leaf area retention in winter barley at for non - QoI fungicides



Order of fungicides at full dose

Fandango
Proline

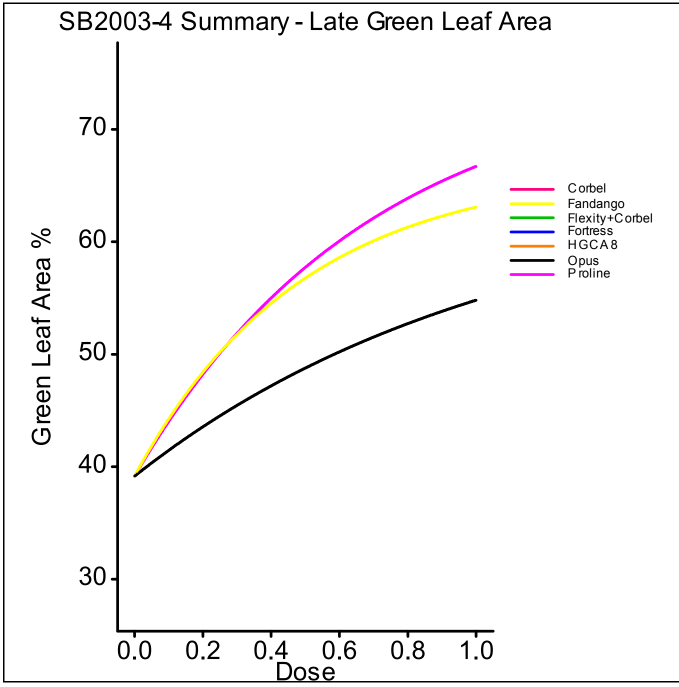
HGCA8 (Tracker)
Flexity + Corbel
Opus

Fortress
Corbel

Figure 14 Green leaf area retention in winter barley for co-formulations and standards

Table 44 Spring barley green leaf area

Fungicide	**% Green leaf area half dose**	**Significance**	**Number of trials**
Bravo_500	65.91	a	3
Proline	57.26	ab	3
Fandango	54.17	abc	2
Opus	51.81	bc	3
Vivid	41.50	cd	2
Acanto	31.28	d	1
Nil	39.16		



Order of fungicides at full dose

Proline

Fandango

Opus

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

Value for money

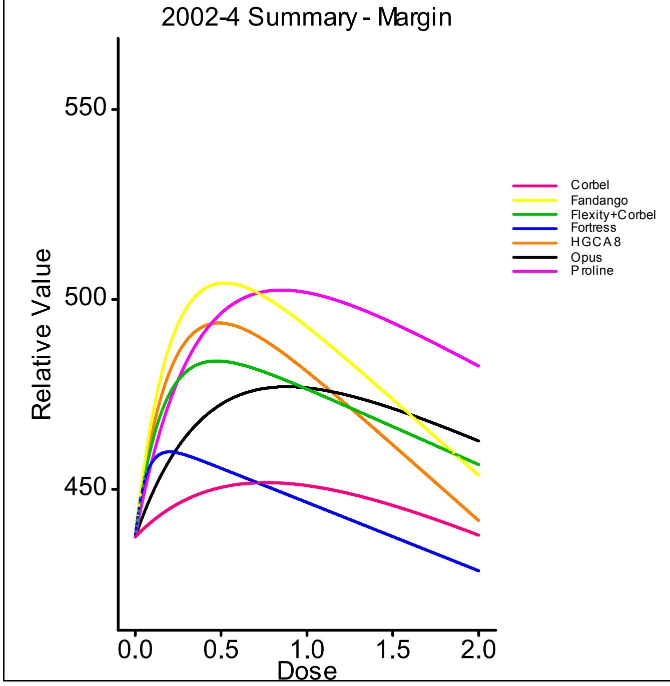
The value for money graphs take account of the yield achieved from each fungicide, the cost of the fungicide and loss in value to reduced specific weight. The grain price set at £70/tonne (Table 45 and Figures 16 – 18).

Table 45 Margin over fungicide cost at half dose

Fungicide	Margin £/ha	Significance	Number of trials	Fungicide type	
Fandango	501	a	12	triazole + QoI	**Best value**
Proline	493	abc	16	triazole	
Tracker	487	abcd	3	triazole + carboxamide	
Flexity+Corbel	482	abcde	3	Unknown + morpholine	
Vivid	476	bcd	13	QoI	
Acanto	475	cd	16	QoI	
Twist	474	cde	9	QoI	
Amistar	470	de	7	QoI	
Opus	469	de	16	triazole	
Unix	459	def	12	anilino pyrimidines	
Neon	459	def	7	morpholine	
Fortress	445	ef	3	quinoline	
Corbel	440	f	11	morpholine	**Lowest value**

Note that significance – fungicides with the same letter are not significantly different. Value of untreated is £400/ha.

Order of fungicides at full dose

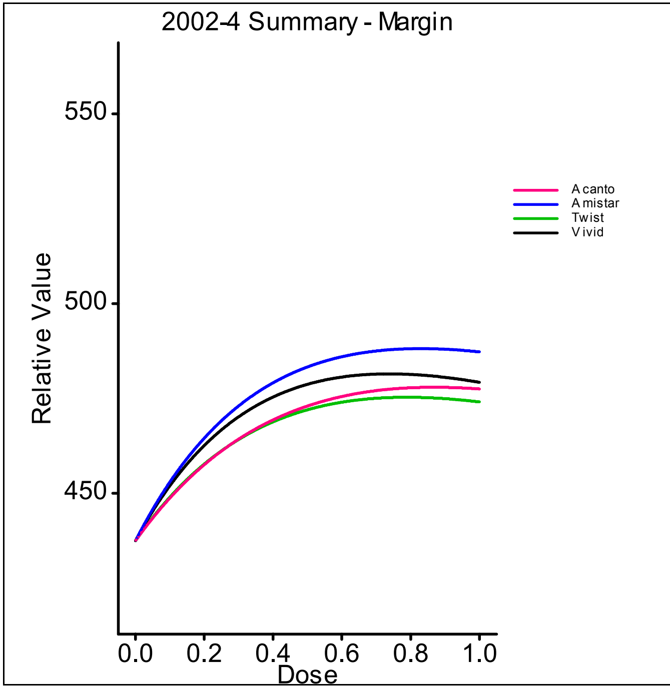


Proline
Fandango

HGCA8 (Tracker)
Flexity + Corbel
Opus

Corbel
Fortress

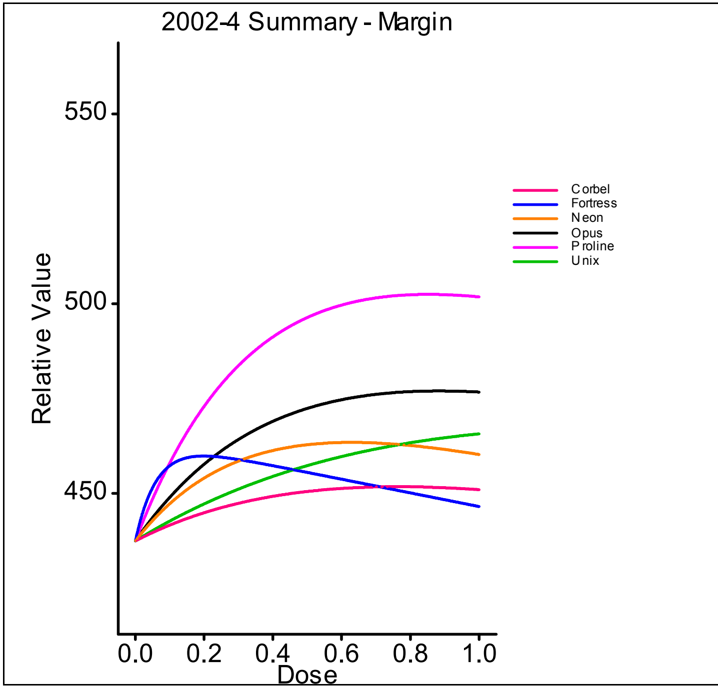
Figure 16 Margin over fungicide costs £/ha in winter barley for QoI fungicides



Order of fungicides at full dose

Amistar
Vivid
Acanto
Twist

Figure 17 Margin over fungicide costs £/ha in winter barley for non QoI fungicides



Order of fungicides at full dose

Proline

Opus
Unix
HGCA8 (Tracker)
Corbel
Fortress

Figure 18 Margin over fungicide costs £/ha in winter barley for co-formulations and standards

At full dose, Proline and Fandango achieved the best margin. Opus and Tracker (HGCA8) were intermediate, whilst Corbel and Fortress were lower. The shape of the curves shows that the optimum dose for Fandango, Proline, Opus, Tracker, Flexity + Corbel and Corbel was approximately half dose. Unix showed better value at the full barley dose.

The curves for all the strobilurin fungicides were similar, and all achieved the optimum margin at approximately two thirds to three quarter dose.

Appropriate fungicide 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 under development in a knowledge transfer initiative funded by SEERAD. It is anticipated that this will be available *via* the SAC web site at www.sac.ac.uk/crops or *via* links from the HGCA web site in mid 2005.

Barley disease control technical note.

Another knowledge transfer initiative was the appropriate dose curves in a technical note funded by SEERAD. A copy of the 2005 note can be found in Appendix 3. A colour version is freely available on the SAC web site.

Discussion

Over the three years of the research, a total of sixteen winter barley trials and three spring barley trials were undertaken. This provides a full set of data for yields, specific weights and green leaf area. When these trials are divided by target disease, the disease with the least data is net blotch. Although disease was recorded in three years, it was only in the final year that disease levels gave the fungicides a real test under field conditions. For the other diseases (rhynchosporium, powdery mildew, and brown rust), the disease pressures in two or three of the years was sufficiently high to give an adequate data set for evaluation of disease protection and eradication. The data set is however less robust for determining shifts in efficacy, though the situation may change after three further years of experimentation. At this stage, any tentative conclusions regarding a shift in efficacy, need to be backed up with results from sensitivity testing.

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. It should be 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. This project has made a start at using this information, but it will require more development to allow growers to input their own values for grain price, fungicide and spraying costs.

As a general guide, the results on yield and value for money show that the new broad-spectrum fungicides Proline, Fandango and Tracker are likely to be cost effective, even though they are likely to have a premium price tag in their first year. Fortress was a fungicide which had a specialised use in mildew protection. Since it has a specific use, the yield response was small.

When yields for trials where the key disease was rhynchosporium, powdery mildew or brown rust were compared, the yield benefit from controlling powdery mildew was lower than that for rhynchosporium or brown rust. The yield response to rhynchosporium and brown rust were very similar. This helps place an order of importance for the three diseases and suggests powdery mildew can be placed as lower priority if savings in fungicides are required. The information on net blotch was too small to place an importance on yield grounds.

Rhynchosporium

Disease level was high in the three 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 new and 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 to the DMI fungicide Opus is known to exist, but in the trials in this study, it performed well, giving good protection and eradication. Tracker, in common with Opus, contains epoxiconazole as one component. Data is limited, but there is a trend towards better protectant activity with Tracker compared to Opus.

Corbel is known as a specialist fungicide giving short term eradicant activity. This was not obvious in these trials. It is possible the effect from this fungicide was shorter than the three weeks between treatment and assessment. Corbel, alongside Neon, did however provide useful protection.

Unix achieved poor eradication and poor to moderate protection at half dose rate. The curves for this fungicide continued upward rather than levelling out. As such, disease protection is increased right up to the full dose rate.

Powdery mildew

Flexity + Corbel achieve the best protection, followed by Proline and Fortress. The fungicides Corbel and Proline achieved the best eradication. Neon was less effective than Corbel at eradicating mildew, but gave similar protectant activity. The DMI fungicides tend to lose efficacy to powdery mildew within a few seasons. Only time will tell if the control from Proline continues once it is used commercially. In the short term however, Proline has useful mildew protection and eradication properties, which are worth exploiting. Research in Denmark came to a similar conclusion. Unix achieved useful mildew protection, but was one of the least effective at eradicating the disease. Flexity + Corbel achieved a better yield response than either Corbel or Fortress. This suggests Flexity may contribute more to yield than through mildew control alone. The control achieved from Acanto (a QoI fungicide) was good in 2002, but more variable in the later two years. There is evidence to suggest that QoI resistance to barley powdery mildew is now widespread, so this result provides further evidence that this group of fungicides should not be relied upon.

Brown rust

Brown rust was relatively straight forward to control with a wide range of fungicides. The QoI fungicides, with the exception of Twist gave good control. Unix was poor at protecting against brown rust, and this is a recognised weakness of this fungicide. The morpholine Neon achieved better eradication and protection than Corbel, suggesting Neon may be a better option of the two morpholines in a mixture in high pressure brown rust situations. Proline gave good control of brown rust, but this fungicide is known to be weaker against wheat brown rust. Although Proline was one of the highest yielding products in mildew and rhynchosporium trials, the overall yields were lower in high pressure brown rust trials.

Net blotch

Data was limited on net blotch, but this may become a more serious disease if QoI resistance becomes widespread. Although data was limited to one year, the results showed the QoI fungicides to be effective, in particular Vivid. Unix also gave good protection, which is useful knowledge, since this is not a QoI fungicide. Neon also gave useful protection, in contrast to Corbel. This suggests Neon may make a useful contribution to net blotch protection. Proline gave similar levels of protection to Neon.

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. Bravo achieved good protection of both types of leaf spots. QoI fungicides were more variable, particularly Acanto. There is a trend towards better reduction in abiotic leaf spots than ramularia with this group of fungicides. The triazole fungicides showed useful reduction of both types of leaf spot. Proline appeared to achieve better protection than Opus.

Green leaf area

In winter barley, the QoI fungicides achieved good levels of green leaf area retention in winter barley. In spring barley, the green leaf area retention was minimal from QoI fungicides, and there is an indication that the optimum greening effect can be achieved from a relative low dose. This poor impact on green leaf may be associated with poor control of leaf spots.

Proline achieves good green leaf area scores in both winter and spring barley. This can be increased further through the use of the coformulated fungicide Fandango. Neon, Corbel and Fortress achieved lower impacts on green leaf area retention. As such, there is a pattern with the better yielding fungicides having greater effect on green leaf area than the lower yielding fungicides.

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 SEERAD funded Technical note which placed the work into a wider context of disease management. It is anticipated this note will be updated in future years. An Appropriate Fungicide Dose Curve Generator will also make the results more accessible to growers in the future. 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.

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, TEAGASC, Carlow, Eire and Dr Lise Nistrup Jørgensesn from Denmark (Jordbrugsforskning Flakkebjerg) 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

Oxley SJP, Cooke LR, Black L, Hunter A, Mercer PC, (2003) Management of Rhynchosporium in different barley varieties and cropping systems, Project Report 315, Home-Grown Cereals Authority.

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

Study Director Signature		**Sponsor Signature**	
Date	-- --- --	Date	-- --- --

Crops Division Study Number 00666

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

Name of Sponsors / Contacts: HGCA Home-Grown Cereals Authority, Caledonia House, 223 Pentonville Road, London N1 9NG.

Tel: 020 7520 3945 Fax: 020 7520 3992

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 2001 – 31 March 2005.
Field work complete 31 October 2004
Final report completion date 31 March 2005

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 3 (2004 Harvest)

Target disease	SAC	ADAS	Morley	TEAGASC	**Total year 3**
powdery mildew	1 (Site 2)	0	0	0	**1**
rhynchosporium	1 (Site 1)	1 (site 3)	0	0	**2**
net blotch	0	0	1 (Site 5)	0	**1**
brown rust	0	1 (Site 4)		0	**1**
ramularia	1 (site 6)*	0	0	1 (Site7)*	**1**
Totals	**3**	**2**	**1**	**1**	**7**

- not HGCA funded.

Trial recognition codes

Target disease	SAC	ADAS	Morley	TEAGASC
powdery mildew	00666(0402)	0	0	0
rhynchosporium	00666(0401)	0	0	0
net blotch	0	00666(0403)	00666(0405)	0
brown rust	0	00666(0404)	0	0
ramularia	00666(0406)	0	0	00666(0407)
Totals	**3**	**2**	**1**	1

Site	**Organisation**	**Site venue**	**Variety**
Site 1	SAC	Lockerbie	Sumo
Site 2	SAC	Bush, Midlothian	Regina
Site 3	ADAS	Cornwall	Sumo
Site 4	ADAS	Terrington	Pearl
Site 5	Morley	East Anglia	Pearl
Site 6	SAC	Bush	Pewter
Site 7	TEAGASC	Carlow	Pewter

To achieve target disease crop may either be winter barley or spring barley. Sac trial on rhynchosporium (site 1) will be aimed at a susceptible winter barley variety (Sumo) at Lockerbie. SAC mildew trial (site 2) will be aimed at susceptible winter barley variety (Regina) at Bush.
Site managers at ADAS Morley and TEAGASC to decide on variety. Please inform Study director of decision

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 [Subject to change in 2004 if new products available]

No	**Powdery mildew**	**Rhynchosporium**	**brown rust**	**Net blotch**	**Ramularia**
	Site 2	*Site 1&3*	*Site 4*	*Site 5*	*Site 6 & 7*
	Opus	Opus	Opus	Opus	Opus
	Corbel	Unix	Corbel	Unix	Amistar
	Fortress	Acanto	Amistar	Amistar	Acanto
	Unix	Vivid	Spiroxamine	Acanto	Vivid
	Spiroxamine	HGCA 3	Acanto	Vivid	HGCA 3
	Acanto +	**HGCA 4**	Vivid	HGCA 3	**HGCA 4**
	HGCA 3	Twist SC (Swift)	HGCA 3	**HGCA 4**	Twist SC(Swift)
	HGCA 5	**HGCA8**	**HGCA 4**	Twist SC (Swift)	**Bravo 500**

+ **Product most likely to be dropped if new fungicide available**

NOTE CHANGES. HGCA 4 is a strobilurin /triazole fungicide from UK958 (HEC/JAU 100+100 EC) barley full dose 1.25 l/ha). Amistar has been removed from the rhynchosporium trial. Caramba has been removed in brown rust, net blotch and ramularia list. HGCA 4 (UK958) will not be tested in Mildew trial. This can be reviewed next season.

HGCA 5 = Flexity + Corbel HGCA6 has not been used due to formulation problems, but it contains the same active ingredient and doses as HGCA5.

HGCA Codes	**Product or company code**
HGCA1	Acanto
HGCA2	Vivid
HGCA3	**Bayer UK756**
HGCA4	UK958
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]

Note HGCA 5 and HGCA 6 are same products but in different formulations. HGCA5 = Flexity + Corbel.

Site 1,3 (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
9	Cyprodinil	Unix	1.34 kg
10	Cyprodinil	Unix	0.67kg
11	Cyprodinil	Unix	0.335 kg
12	Cyprodinil	Unix	0.168 kg
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	BAS500/Vivid	2.00 litre
22	Pyraclostrobin	BAS500/Vivid	1.00 litre
23	Pyraclostrobin	BAS500/Vivid	0.50 litre
24	Pyraclostrobin	BAS 500/Vivid	0.25 litre
25	HGCA3	Bayer UK756	1.60 litre
26	HGCA3	Bayer UK756	0.80 litre
27	HGCA3	Bayer UK756	0.40 litre
28	HGCA3	Bayer UK756	0.20 litre
29	HGCA4	UK958	2.50 litres
30	HGCA4	UK958	1.25 litres
31	HGCA4	UK958	0.625 litre
32	HGCA4	UK958	0.3125 litres
33	Untreated	---	---
34	Untreated	---	---
35	Untreated	----	
36	Untreated	----	
53	Trifloxystrobin	Twist SC (Swift)	1.0
54	Trifloxystrobin	Twist SC(Swift)	0.5
55	Trifloxystrobin	Twist SC(Swift)	0.25
56	Trifloxystrobin	Twist SC(Swift)	0.125
65	HGCA8	BAS549	3.0
66	HGCA8	BAS549	1.5
67	HGCA8	BAS549	0.75
68	HGCA8	BAS549	0.375

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
5		Fenpropimorph	Corbel	2.00 litre
6		Fenpropimorph	Corbel	1.00 litre
7		Fenpropimorph	Corbel	0.50 litre
8		Fenpropimorph	Corbel	0.25 litre
37		Quinoxyfen	Fortress	0.60 litre
38		Quinoxyfen	Fortress	0.30 litre
39		Quinoxyfen	Fortress	0.15 litre
40		Quinoxyfen	Fortress	0.075 litre
9		Cyprodinil	Unix	1.34 kg
10		Cyprodinil	Unix	0.67kg
11		Cyprodinil	Unix	0.335 kg
12		Cyprodinil	Unix	0.168 kg
41		Spiroxamine	Neon	3.00 litre
42		Spiroxamine	Neon	1.50 litre
43		Spiroxamine	Neon	0.75 litre
44		Spiroxamine	Neon	0.375 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
25		HGCA3	Bayer UK756	1.60 litre
26		HGCA3	Bayer UK756	0.80 litre
27		HGCA3	Bayer UK756	0.40 litre
28		HGCA3	Bayer UK756	0.20 litre
49		HGCA5	BAS564	3.0 litres
50		HGCA5	BAS564	1.5 litres
51		HGCA5	BAS564	0.75 litre
52		HGCA5	BAS564	0.375 litres
33		Untreated	---	---
34		Untreated	---	---
35		Untreated	----	
36		Untreated	----	

New code is to allow cross comparisons using identical numbers for a specific product and dose
+ If new product available, it should be used in place of Acanto.

Site 4 (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
5		Fenpropimorph	Corbel	2.00 litre
6		Fenpropimorph	Corbel	1.00 litre
7		Fenpropimorph	Corbel	0.50 litre
8		Fenpropimorph	Corbel	0.25 litre
45		Azoxystrobin	Amistar	2.00 litre
46		Azoxystrobin	Amistar	1.00 litre
47		Azoxystrobin	Amistar	0.50 litre
48		Azoxystrobin	Amistar	0.25 litre
41		Spiroxamine	Neon	3.00 litre
42		Spiroxamine	Neon	1.50 litre
43		Spiroxamine	Neon	0.75 litre
44		Spiroxamine	Neon	0.375 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	BAS500/Vivid	2.00 litre
22		Pyraclostrobin	BAS500/Vivid	1.00 litre
23		Pyraclostrobin	BAS500/Vivid	0.50 litre
24		Pyraclostrobin	BAS 500/Vivid	0.25 litre
25		HGCA3	Bayer UK756	1.60 litre
26		HGCA3	Bayer UK756	0.80 litre
27		HGCA3	Bayer UK756	0.40 litre
28		HGCA3	Bayer UK756	0.20 litre
29		HGCA4	UK958	2.50 litres
30		HGCA4	UK958	1.25 litres
31		HGCA4	UK958	0.625 litre
32		HGCA4	UK958	0.3125 litres
33		Untreated	---	---
34		Untreated	---	---
35		Untreated	----	
36		Untreated	----	

Site5 (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
9		Cyprodinil	Unix	1.34 kg
10		Cyprodinil	Unix	0.67kg
11		Cyprodinil	Unix	0.335 kg
12		Cyprodinil	Unix	0.168 kg
45		Azoxystrobin	Amistar	2.00 litre
46		Azoxystrobin	Amistar	1.00 litre
47		Azoxystrobin	Amistar	0.50 litre
48		Azoxystrobin	Amistar	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	BAS500/Vivid	2.00 litre
22		Pyraclostrobin	BAS500/Vivid	1.00 litre
23		Pyraclostrobin	BAS500/Vivid	0.50 litre
24		Pyraclostrobin	BAS 500/Vivid	0.25 litre
25		HGCA3	Bayer UK756	1.60 litre
26		HGCA3	Bayer UK756	0.80 litre
27		HGCA3	Bayer UK756	0.40 litre
28		HGCA3	Bayer UK756	0.20 litre
29		HGCA4	UK958	2.50 litres
30		HGCA4	UK958	1.25 litres
31		HGCA4	UK958	0.625 litre
32		HGCA4	UK958	0.3125 litres
33		Untreated	---	---
34		Untreated	---	---
35		Untreated	----	---
36		Untreated	----	---
53		Trifloxystrobin	Twist SC (Swift)	1.0
54		Trifloxystrobin	Twist SC(Swift)	0.5
55		Trifloxystrobin	Twist SC(Swift)	0.25
56		Trifloxystrobin	Twist SC(Swift)	0.125

Site 6 & 7 (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
45		Azoxystrobin	Amistar	2.00 litre
46		Azoxystrobin	Amistar	1.00 litre
47		Azoxystrobin	Amistar	0.50 litre
48		Azoxystrobin	Amistar	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	Vivid	2.00 litre
22	*	Pyraclostrobin	Vivid	1.00 litre
23	*	Pyraclostrobin	Vivid	0.50 litre
24	*	Pyraclostrobin	Vivid	0.25 litre
25	*	HGCA3	Bayer UK756	1.60 litre
26	*	HGCA3	Bayer UK756	0.80 litre
27	*	HGCA3	Bayer UK756	0.40 litre
28	*	HGCA3	Bayer UK756	0.20 litre
29	*	HGCA4	UK958	2.50 litres
30	*	HGCA4	UK958	1.25 litres
31	*	HGCA4	UK958	0.625 litre
32	*	HGCA4	UK958	0.3125 litres
33	*	Untreated	---	---
34	*	Untreated	---	---
35	*	Untreated	----	
36	*	Untreated	----	
53		Trifloxystrobin	Twist SC (Swift)	1.0
54		Trifloxystrobin	Twist SC(Swift)	0.5
55		Trifloxystrobin	Twist SC(Swift)	0.25
56		Trifloxystrobin	Twist SC(Swift)	0.125
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

* Treatments in SAC trial.

Treatment list for 2004 harvest New code is unique number which must be used in datasheets

New code	Treatment	Active ingredient	Product	Rate product/ha	£/ha	Group
1	1	Epoxiconazole	Opus	2.00 litre	40	NM
2	2	Epoxiconazole	Opus	1.00 litre	20	NM
3	3	Epoxiconazole	Opus	0.50 litre	10	NM
4	4	Epoxiconazole	Opus	0.25 litre	5	NM
5	5	Fenpropimorph	Corbel	2.00 litre	40	NM
6	6	Fenpropimorph	Corbel	1.00 litre	20	NM
7	7	Fenpropimorph	Corbel	0.50 litre	10	NM
8	8	Fenpropimorph	Corbel	0.25 litre	5	NM
9	13	Cyprodinil	Unix	1.34 kg	28	N
10	14	Cyprodinil	Unix	0.67kg	14	N
11	15	Cyprodinil	Unix	0.335 kg	7	N
12	16	Cyprodinil	Unix	0.168 kg	3.5	N
13	13	Trifloxystrobin	Twist EC	4.00 litre	60	S
14	14	Trifloxystrobin	Twist EC	2.00 litre	30	S
15	15	Trifloxystrobin	Twist EC	1.00 litre	15	S
16	16	Trifloxystrobin	Twist EC	0.50 litre	7.5	S
17	21	Picoxystrobin	Acanto	2.00 litre	60	S
18	22	Picoxystrobin	Acanto	1.00 litre	30	S
19	23	Picoxystrobin	Acanto	0.50 litre	15	S
20	24	Picoxystrobin	Acanto	0.25 litre	7.5	S
21	21	Pyraclostrobin	Vivid	2.00 litre	64	S
22	22	Pyraclostrobin	Vivid	1.00 litre	32	S
23	23	Pyraclostrobin	Vivid	0.50 litre	16	S
24	24	Pyraclostrobin	Vivid	0.25 litre	8	S
25	25	HGCA3	Bayer UK756	1.60 litre	50	NM
26	26	HGCA3	Bayer UK756	0.80 litre	25	NM
27	27	HGCA3	Bayer UK756	0.40 litre	12.5	NM
28	28	HGCA3	Bayer UK756	0.20 litre	6.25	NM
29	29	HGCA4	UK958	2.50 litres	80	M
30	30	HGCA4	UK958	1.25 litres	40	M
31	31	HGCA4	UK958	0.625 litre	20	M
32	32	HGCA4	UK958	0.3125 litres	10	M
33	33	Untreated	---	---	0	SNM
34	34	Untreated	---	---	0	SNM
35	35	Untreated	----	---	0	SNM
36	36	Untreated	----	---	0	SNM
37	9	Quinoxyfen	Fortress	0.60 litre	36	NM
38	10	Quinoxyfen	Fortress	0.30 litre	18	NM
39	11	Quinoxyfen	Fortress	0.15 litre	9	NM
40	12	Quinoxyfen	Fortress	0.075 litre	4.5	NM
41	17	Spiroxamine	Neon	3.00 litre	44	N
42	18	Spiroxamine	Neon	1.50 litre	22	N
43	19	Spiroxamine	Neon	0.75 litre	11	N
44	20	Spiroxamine	Neon	0.375 litre	5.5	N

New code	Treatment	Active ingredient	Product	Rate product/ha	£/ha	Group
45	9	Azoxystrobin	Amistar	2.00 litre	56	S
46	10	Azoxystrobin	Amistar	1.00 litre	28	S
47	11	Azoxystrobin	Amistar	0.50 litre	14	S
48	12	Azoxystrobin	Amistar	0.25 litre	7	S
49	29	HGCA5	BAS560 + Corbel (Flexity + Corbel)	**BAS560 1.0 l/ha + Corbel 1.08 l/ha**	40	M
50	30	HGCA5	BAS560 + Corbel (Flexity + Corbel)	**BAS560 0.5 l/ha + Corbel 0.54 l/ha**	20	M
51	31	HGCA5	BAS560 + Corbel (Flexity + Corbel)	**BAS560 0.25 l/ha + Corbel 0.27 l/ha**	10	M
52	32	HGCA5	BAS560 + Corbel (Flexity + Corbel)	**BAS560 0.125 l/ha + Corbel 0.135 l/ha**	5	M
53	53	Trifloxystrobin	Twist SC (Swift)	1.0	60	S
54	54	Trifloxystrobin	Twist SC(Swift)	0.5	30	S
55	55	Trifloxystrobin	Twist SC(Swift)	0.25	15	S
56	56	Trifloxystrobin	Twist SC(Swift)	0.125	7.5	S
57	57	Chlorothalonil	Bravo 500	4.0 l/ha	16	N
58	58	Chlorothalonil	Bravo 500	2.0 l/ha	8	N
59	59	Chlorothalonil	Bravo 500	1.0 l/ha	4	N
60	60	Chlorothalonil	Bravo 500	0.5 l/ha	2	N
61	61	HGCA6	BAS564	3.0 litres	40	M
62	62	HGCA6	BAS564	1.5 litres	20	M
63	63	HGCA6	BAS564	0.75 litre	10	M
64	64	HGCA6	BAS564	0.375 litres	5	M
65	65	HGCA8	BAS549 (Opus+BAS510)	3.0 litres	80	M
66	66	HGCA8	BAS549(Opus+BAS510)	1.5 litres	40	M
67	67	HGCA8	BAS549(Opus+BAS510)	0.75 litre	20	M
68	68	HGCA8	BAS549(Opus+BAS510)	0.375 litres	10	M

Twist formulation will be SC for 2003 (also known as Swift). It has been given a new treatment number.

£/ha based on 2004 season prices. For experimental products, no commercial price is available, so it based around the price of equivalent products on the market.

Group is group for summary graphs

S = Strobilurin fungicide
N = Non Strobilurin fungicide
M= Fungicide co-formulations and individual components (Note this will include products in above 2 groups
Group is group for summary graphs
Note Proline will be £38/litre
Fandango will be £28/litres

S = Strobilurin fungicides
N = Non Strobilurin fungicide
M= Co-formulation and individual components (Note this will include products in above 2 groups

Strobilurins (S)	Colour	Strobilurins (S)	Non-strobilurins (N)	Colour	No-Strobilurins (N)	Mixtures & Components (M)	colour	Mixtures & Components (M)
			Opus	Black	1 2 3 4	Opus	Black	1 2 3 4
Acanto	Red	17 18 19 20	Corbel	Red	5 6 7 8	Corbel	Red	5 6 7 8
Vivid	Black	21 22 23 24	Unix	Green	9 10 11 12	HGCA3 (Proline)	Purple	25 26 27 28
Amistar	Blue	45 46 47 48	HGCA3 (Proline)	Purple	25 26 27 28	HGCA4 (Fandango)	yellow	29,30,31,32
Twist	Green	53 54 55 56	Fortress	Blue	37 38 39 40	Fortress	Blue	37 38 39 40
			Neon	Orange	41 42 43 44	HGCA5 (Flexity+Corbel)	Green	49 50 51 52
			Bravo	yellow	57 58 59 60	HGCA8	Orange	65 66 67 68

Please note:
HGCA 3 can be called Proline
HGCA4 can be called Fandango
HGCA 5 can now be called Flexity + Corbel

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.

Plot	Block	Treatment	Plot	Block	Treatment	Plot	Block	Treatment
1	1		37	2		73	3	
2	1		38	2		74	3	
3	1		39	2		75	3	
4	1		40	2		76	3	
5	1		41	2		77	3	
6	1		42	2		78	3	
7	1		43	2		79	3	
8	1		44	2		80	3	
9	1		45	2		81	3	
10	1		46	2		82	3	
11	1		47	2		83	3	
12	1		48	2		84	3	
13	1		49	2		85	3	
14	1		50	2		86	3	
15	1		51	2		87	3	
16	1		52	2		88	3	
17	1		53	2		89	3	
18	1		54	2		90	3	
19	1		55	2		91	3	
20	1		56	2		92	3	
21	1		57	2		93	3	
22	1		58	2		94	3	
23	1		59	2		95	3	
24	1		60	2		96	3	
25	1		61	2		97	3	
26	1		62	2		98	3	
27	1		63	2		99	3	
28	1		64	2		100	3	
29	1		65	2		101	3	
30	1		66	2		102	3	
31	1		67	2		103	3	
32	1		68	2		104	3	
33	1		69	2		105	3	
34	1		70	2		106	3	
35	1		71	2		107	3	
36	1		72	2		108	3	

12. MATERIALS

Materials required are detailed in the appropriate SOPs.

13. METHODS

13.1 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

14. 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.

14.1 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.

14.1.1 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, so that the first of these assessments records maximum disease expression on EL3, and the second assessment the maximum disease expression on EL1 and EL2.

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. 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 <u>one</u> 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:

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

(b) 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.

(c) 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.

Disease assessments become less accurate once the % green leaf area (GLA) falls below an average of 25%. Different treatments will reach 25% GLA on a given leaf layer at different times, and may therefore differ in the number of leaf layers that can be assessed. Therefore: i) for each plot decide how many leaf layers can be assessed (i.e. all the layers down to, and including an average of 25% GLA) and ii) assess that many leaf layers for all 10 stems from that plot (even though some individual leaves will have less than 25% GLA). **Continue to record % GLA for each leaf layer until all leaves are completely senescent, even when disease assessment has finished for that leaf layer**.

Ear diseases

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.

14.1.3 Stem base diseases

14.1.4 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.

14.2 Growth Stage

Record growth stage on each assessment date.

14.3 Lodging

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

14.4 Grain Yield

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

14.5 Grain Quality

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

14.6 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

14.7 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.

15. DATA HANDLING

15.3 Data collation

Data should be transferred to Excel spreadsheets as soon as possible after collection. Send disease data when complete to s.oxley@ed.sac.ac.uk and Tony Hunter <T.Hunter@bioss.sari.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 2004 TRIALS. DO NOT USE 2003 DATA SHEET

16. REPORTS

Site reports to be produced by 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 2005.

17. 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.

18. 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

20. DISTRIBUTION

Study Director:	Simon Oxley
Reports Co-ordinator:	Simon Oxley
Site Manager, Site 1&2&6	Simon Oxley
Site Manager Site 3	David Lockley
Site Manager, Sites 4	Peter Gladders
Site Manager, Sites 5	Mike Nuttall, Marion
Site manager site 7	Jim Burke
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 www.bioss.ac.uk/afdbarley at end of season

Reporting date Final report March 2005

Archiving of documentation and samples. SAC

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

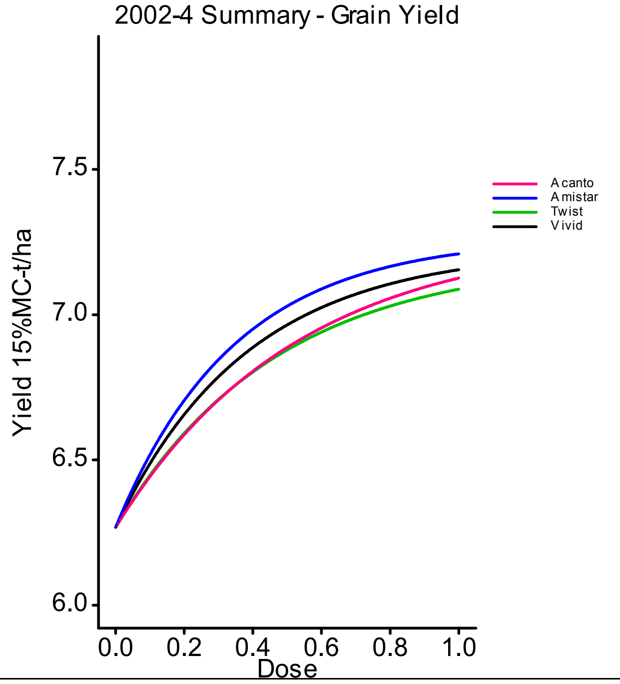
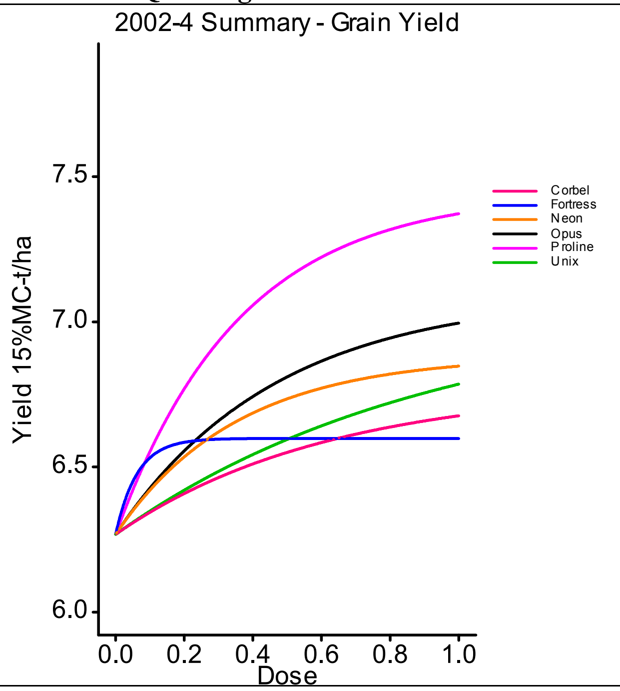
Study	Spray date	Spray Gs	Leaf fully emerged	Leaf emerging
666(0401)				
666(0402)				
666(0403)				
666(0404)				
666(0405)				
666(0406)				
666(0407)				

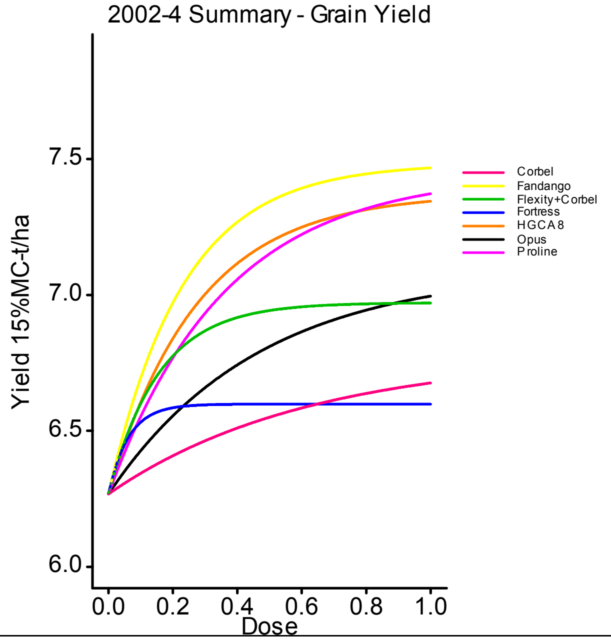
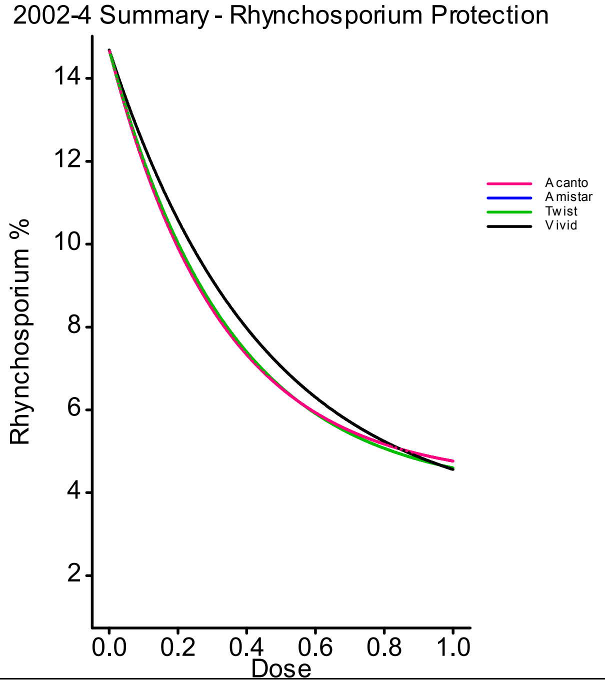
END of PROTOCOL

QA Signature	**Date**

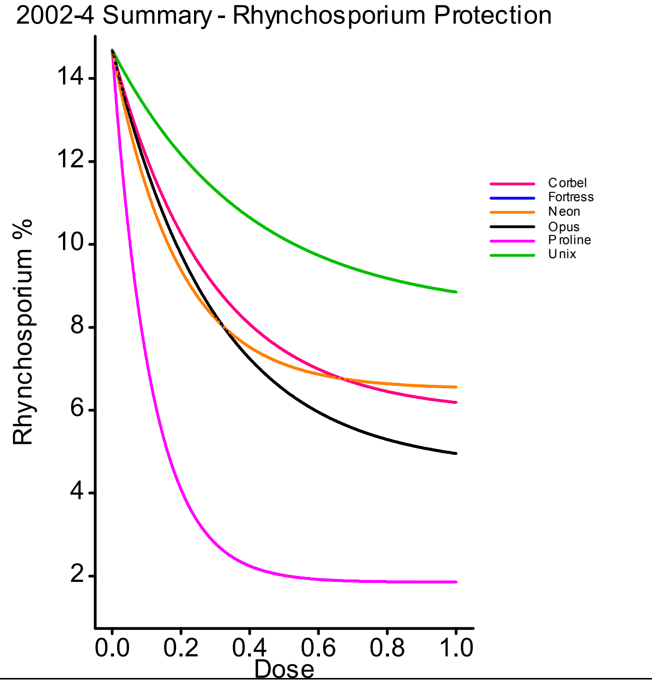
Appendix 2 Winter barley curve summaries for yield and disease protection 2002-2004

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**
	Amistar Vivid Acanto Twist
Yields non QoI fungicides	**Order of fungicides at full dose**
	Proline Opus Neon Unix Corbel Fortress

Yields co-formulations & standards	Order of fungicides at full dose
	Fandango Proline HGCA8 Tracker Opus Flexity + Corbel Corbel Fortress
Rhynchosporium protection QoI fungicides	**Order of fungicides at full dose**
	Acanto Twist Vivid

Rhynchosporium protection QoI fungicides



Order of fungicides at full dose

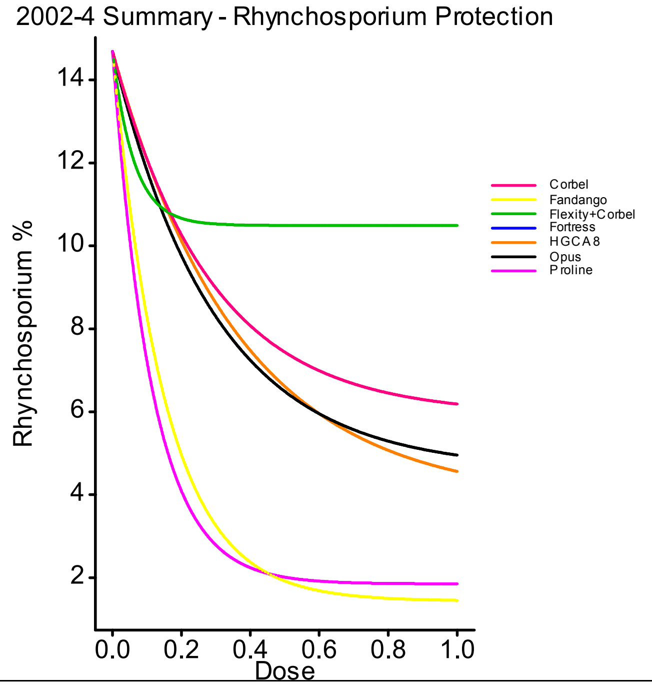
Unix

Neon
Corbel

Opus

Proline

Rhynchosporium protection co-formulations & standards



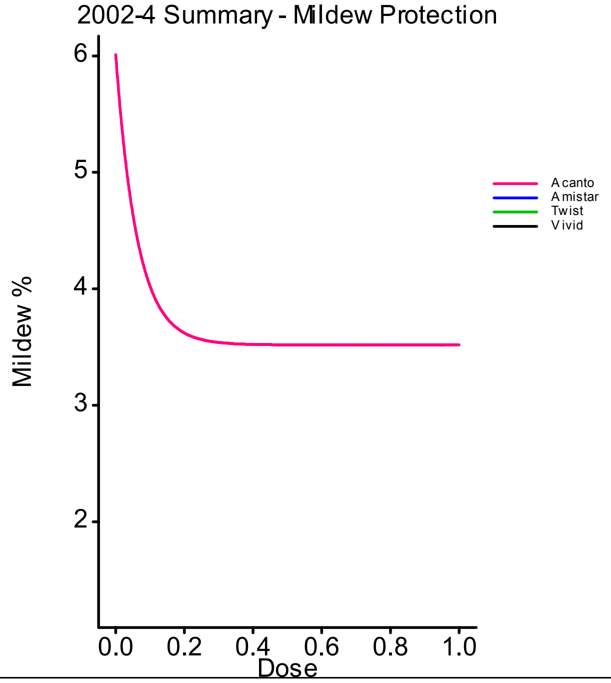
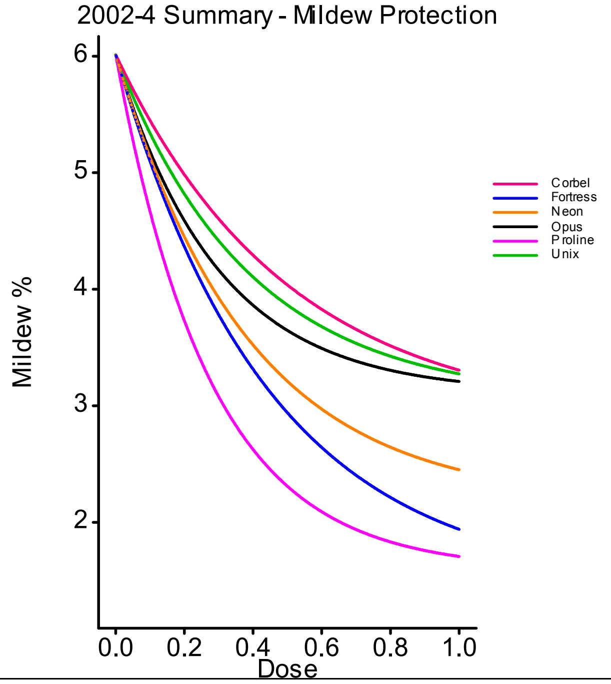
Order of fungicides at full dose

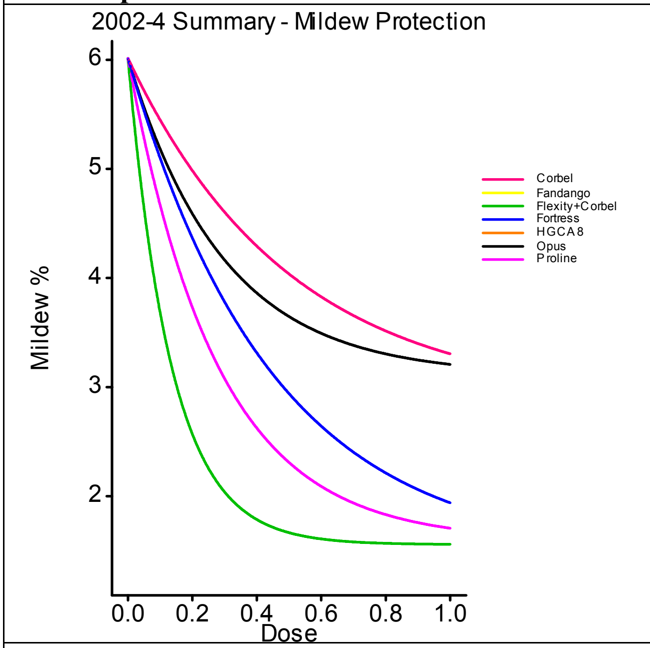
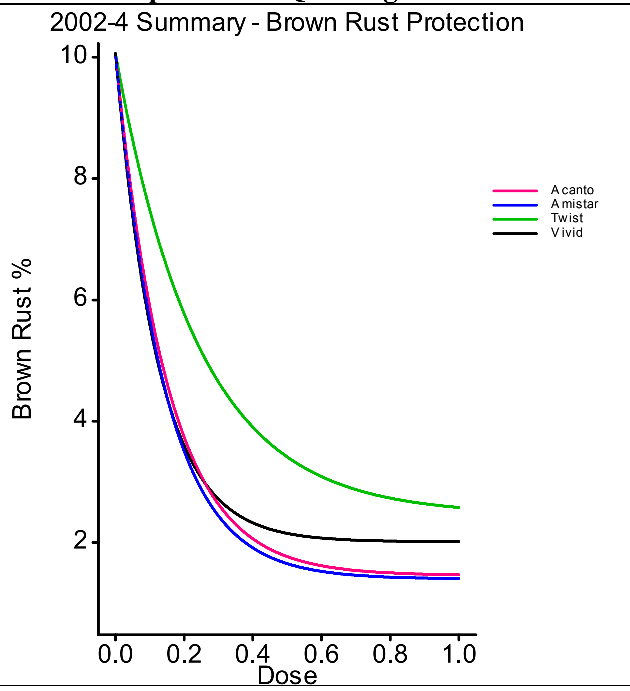
Flexity + Corbel

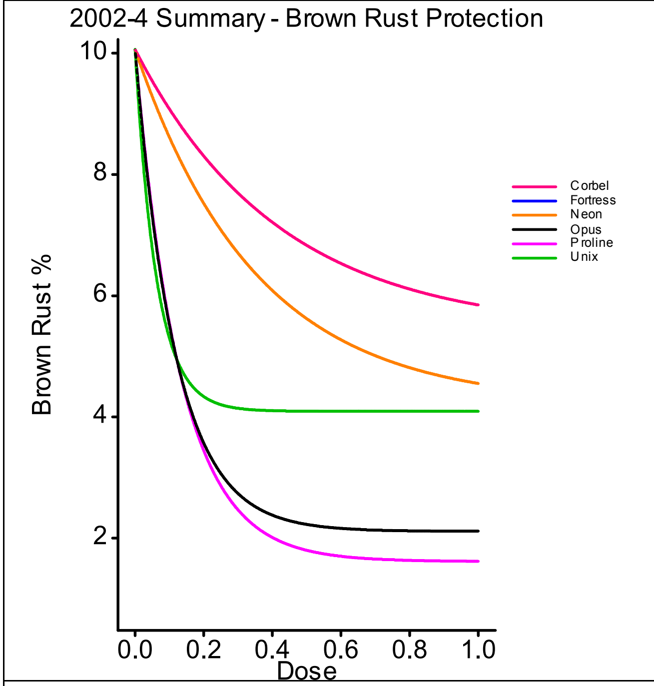
Corbel

Opus
HGCA8 Tracker

Proline
Fandango

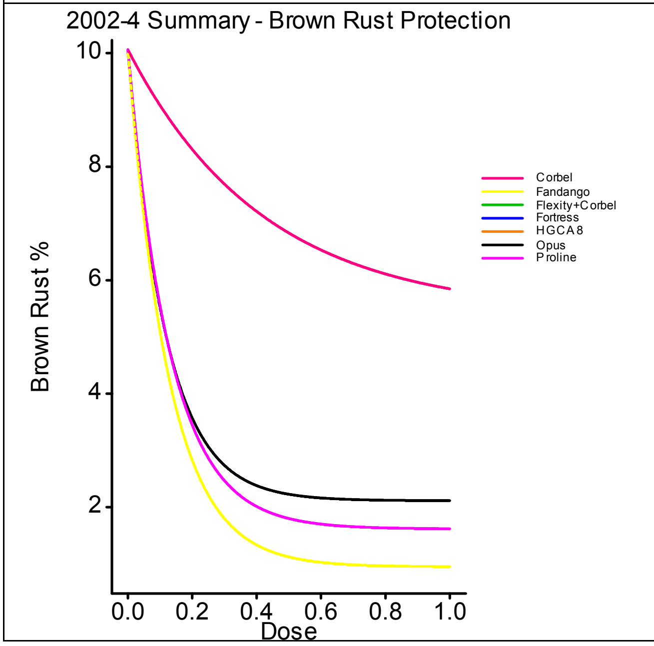
Mildew protection QoI fungicides	Order of fungicides at full dose
	Acanto
Mildew protection non QoI fungicides	**Order of fungicides at full dose**
	Corbel Unix Opus Neon Fortress Proline

Mildew protection co-formulations & standards	Order of fungicides at full dose
	Corbel Opus Fortress Proline Flexity + Corbel
Brown rust protection QoI fungicides	**Order of fungicides at full dose**
	Twist Vivid Acanto Amistar

<table>
<tr><th>Brown rust protection Non QoI fungicides</th><th>Order of fungicides at full dose</th></tr>
<tr><td>
</td><td>Corbel

Neon

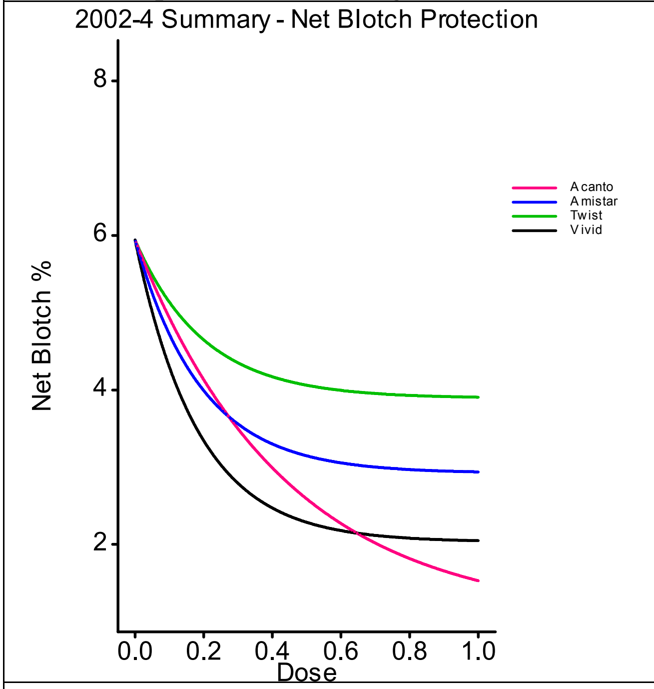
Unix

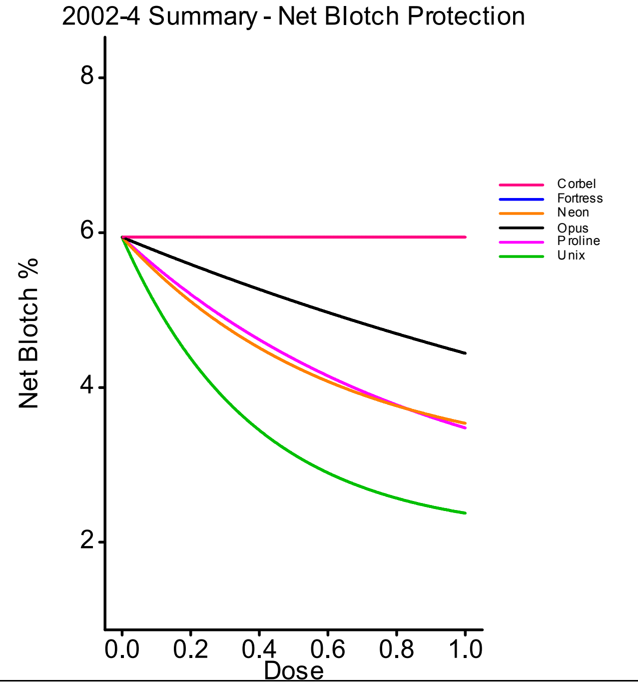
Opus
Proline</td></tr>
<tr><th>Brown rust protection co-formulations & standards</th><th>Order of fungicides at full dose</th></tr>
<tr><td>
</td><td>Corbel

Opus

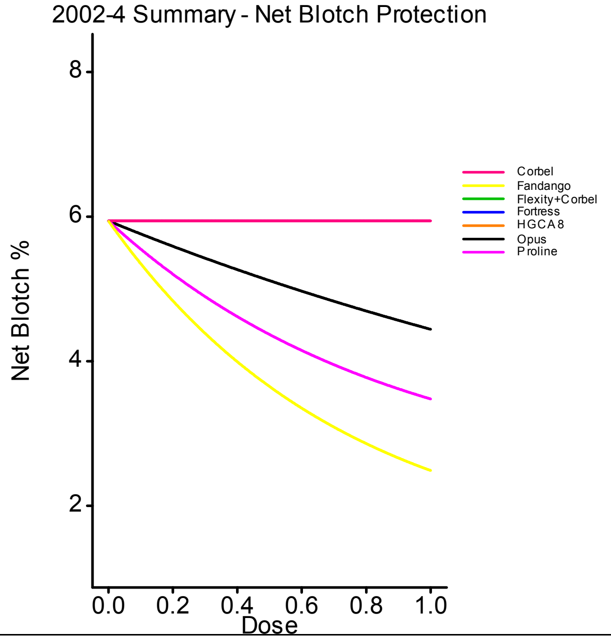
Proline

Fandango</td></tr>
</table>

<table>
<tr><th>Net blotch protection QoI fungicides</th><th>Order of fungicides at full dose</th></tr>
<tr><td>


</td><td>Twist
Amistar
Vivid
Acanto</td></tr>
<tr><th>Net blotch protection non QoI fungicides</th><th>Order of fungicides at full dose</th></tr>
<tr><td>


</td><td>Corbel
Opus
Neon
Proline
Unix</td></tr>
</table>

Net blotch protection co-formulations & standards	**Order of fungicides at full dose**
	Corbel Opus Proline Fandango

Appendix 3 Technical note on barley

A technical note funded by SEERAD was published in 2004 and updated in 2005. The note places the appropriate dose work into a broader context of disease management in barley. A copy of the 2005 edition is 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